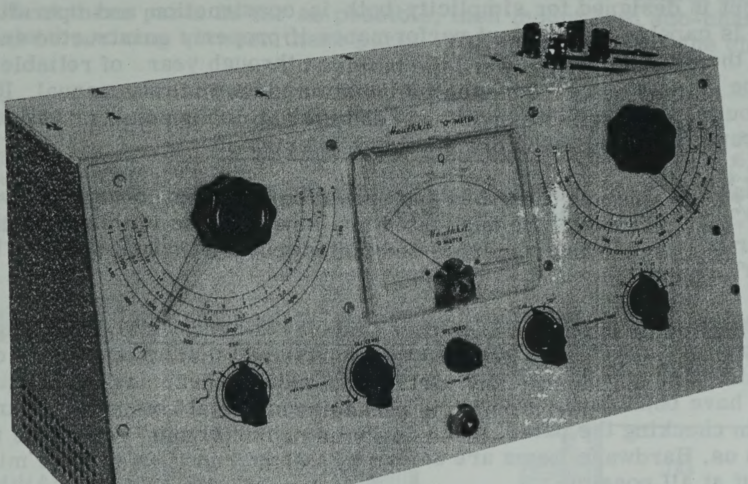
HEATHKIT
MODEL QM-1
Q-METER



SPECIFICATIONS

Power Requirements	115 volts AC 50/60 cycles 30 watts
Tube Complement	1 - 12AT7 Oscillator
	1 - 6AL5 VTVM diode
	1 - 12AU7 VTVM amplifier
	1 - OD3/VR150 Regulator
	1 - 6X5 Rectifier
Frequency Range	150 KC - 18 MC
Inductance Scale Range	1 micro H. - 10 milli H.
Actual Capacity Scale Range	40 MMF - 450 MMF
Effective Capacity Scale Range	40 MMF 400 MMF
Vernier Capacity Scale Range	-3 MMF - +3 MMF
"Q" Scale Range	250 Full scale x1 or x2
Dimensions	8" high x 17" wide x 6" deep

ASSEMBLY AND OPERATION OF THE
HEATHKIT MODEL QM-1 Q-METER

The Heathkit Q Meter is a device of particular value in work with resonant circuits within the frequency and capacity ranges of the instrument.

It enables the user to measure the performance of such circuits and their component parts at the operating frequency and thus makes it possible to predict their operation in actual use.

The instrument is designed for simplicity both in construction and operation. But despite its simplicity, it is capable of excellent performance if properly constructed and intelligently used. Care used in the assembly will reward the builder through years of reliable service. Maximum results will be obtained by following the information given in this manual. It is, therefore, suggested that you take a few minutes now and read the entire manual, or at least the parts pertaining to the assembly and testing before any work is started.

Large pictorial diagrams are furnished and should be attached above the work space for your convenience. These pictorials are duplicated in a smaller size in this manual. The large prints may be discarded after the instrument is completed, but the manual should be retained in your files for future reference.

Unpack the kit carefully and check each part against the parts list. In doing this, you will become acquainted with each part. Refer to the charts and other information on the inside covers of this manual to help you identify any parts about which there may be a question. Make sure that all parts have been removed from the packaging material before it is thrown out. If a shortage is found in checking the parts, please notify us promptly and return the inspection slip with your letter to us. Hardware items are counted by weight, and if a few are missing, please obtain them locally if at all possible.

Resistors and controls generally have a tolerance rating of plus or minus 20% unless otherwise stated in the parts list. Thus a 10,000 ohm resistor may test anywhere from 8,000 ohms to 12,000 ohms. The tolerance on condensers is frequently even greater. This Heathkit is designed to accommodate such variations.

Small changes in parts may be made by the Heath Company. Such changes will not adversely affect the operation of the instrument, and will only be made to insure a minimum delay in filling your order.

Read the note on soldering on the inside back cover. Use only good quality rosin core radio type solder. Pastes or acids, while making soldering even easier, do not result in a joint satisfactory for radio work. Their cleaning action is based on a corroding effect, even if they are called "non-corrosive." They are very difficult to remove completely after the joint is made, and even a minute quantity left behind combines with moisture in the air to form a highly corrosive and conductive product. Thus weeks or months later the continued corrosion may "eat up" the wire or the joint causing failure through open circuits, or the conduction through the growing deposit may cause sufficient leakage to prevent proper operation.

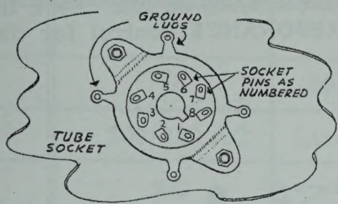
NOTE: All guarantees are voided and we will not repair or service instruments in which acid core solder or pastes are used. (When in doubt about solder, it is recommended that a new roll plainly marked "Rosin Core Radio Solder" be purchased.)

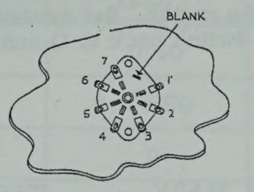
CONSTRUCTION

Many components are supplied by the manufacturers with leads that are longer than the particular application requires. Of course, all excess lead lengths should be removed so as to permit neat and direct installation of the components involved. Following this procedure will very definitely result in superior operation of the instrument and will afford you a sense of satisfaction and pride in having constructed a neat and professional appearing instrument.

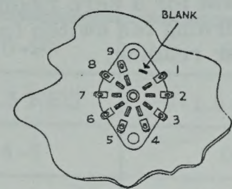
Whenever necessary, use spaghetti or insulated sleeving over bare wires on condensers or resistors to prevent the leads from accidentally touching adjacent terminals, wires or metal parts.

Assemble the generator sub-chassis, the "Q" sub-chassis, the main chassis and the panel separately. Wire the first three parts as far as possible, then mount both sub-chassis on the main chassis and complete the wiring between these parts. Attach the panel to the chassis and complete the wiring.



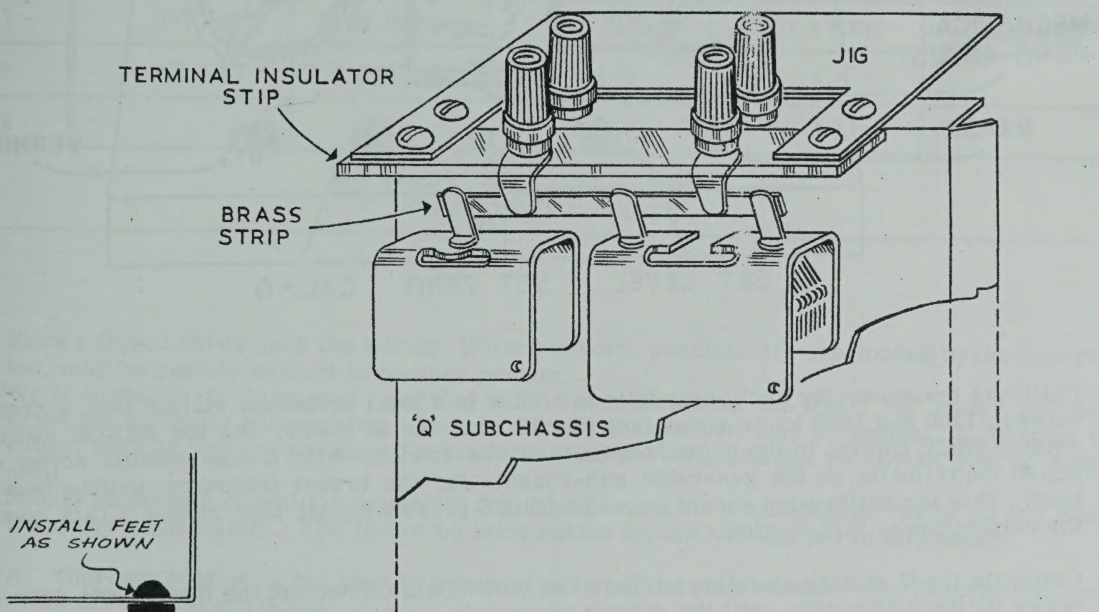


PIN NUMBERING ON MINIATURE TUBE SOCKET



PIN NUMBERING ON NOVAL TUBE SOCKET

Note: Make sure the miniature and noval tube sockets are free from obstructions before inserting the tubes. These small tubes are fairly fragile and broken tubes are not covered by any guarantee.



NOTE: After the tuning condensers are mounted on the "Q" sub-chassis, temporarily fasten the jig to the "Q" sub-chassis and to the insulated terminal strip (with the binding posts attached). Solder the brass strip to the terminal strip solder lugs and the lugs on the tuning condensers. Now the jig can be removed and discarded.

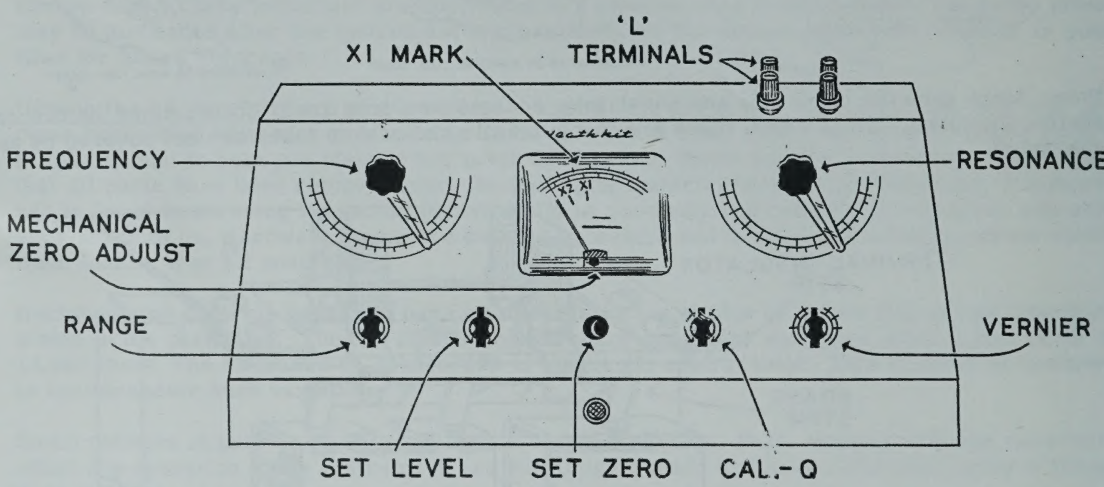
TEST AND CALIBRATION

Check the wiring carefully before proceeding. Inspect all solder connections and make sure that no stray wires or excess solder can cause short circuits between adjacent contacts on sockets and switches.

Plug the line cord into a 117 volt 50-60 cycle AC outlet. CAUTION: Do not connect to a DC outlet for this will seriously damage the power transformer.

Set the CAL-Q switch to CAL and turn the SET LEVEL control clockwise. After a minute warmup observe that the level can be set to the red X1 mark on the meter. Turn the generator RANGE switch and FREQUENCY control to make sure that the X1 reading can be obtained at all frequencies.

Insert the test coil in the "L" terminals. Set the CAL-Q switch to Q and adjust the SET ZERO control for a zero reading on the meter. Set generator section to 1,000 kc and check the level by turning the switch to CAL. Switch back to Q and adjust RESONANCE control for maximum meter reading.



Calibrate the generator section as follows: Tune in a local broadcast station with a frequency between 1200 and 1500 kc on a receiver placed near the Q meter. Set the RANGE switch and FREQUENCY control to the same frequency as the station. With a non-metallic screw driver adjust the trimmer on the generator sub-chassis for the lowest frequency audible beat (zero beat). Now the calibration should be well within 3 percent on all four ranges. This completes the calibration of this section.

Calibrate the Q section as follows: Turn the instrument off and set the mechanical zero-adjust screw on the meter case until the pointer accurately reads zero. Turn the instrument on again. Set the generator section to 1,000 kc and adjust the level to the X1 mark. Switch to Q and turn RESONANCE control for maximum indication. With a non-metallic screw driver adjust the trimmer on the Q sub-chassis until the meter reads the Q value indicated on the test coil. Set the VERNIER to O and adjust the pointer on the shaft of the RESONANCE control to read on the C_E scale the capacity indicated on the test coil. This completes the calibration.

IN CASE OF DIFFICULTY

If the instrument fails to perform as outlined in the foregoing section, proceed as follows:

1. Read the next section entitled "Principles of Operation." A thorough understanding of the circuits used may reveal the cause for difficulties.
2. Check the voltages at the tube sockets and compare them with representative readings tabulated below. Substantial deviation from the tabulated values would point to a particular portion of the circuit. Further investigation of that portion may reveal the cause.

	VOLTAGE TABLE				
	6X5	OD3	12AT7	12AU7	6AL5
1	NC	T 1-4	0-80	70-90	0
2	0	60-80 NEG	0-5 NEG	0-1.5 NEG	0-1.5 NEG
3	200-220 AC	Line Jumper	0	4-5	0
4	NC	NC	0	0	4-6 AC
5	200-220 AC	70-90	0	0	0
6	T 140-160	NC	120-150	70-90	0
7	5-7 AC	Line Jumper	0	0-1.5 NEG	0-1.5 NEG
8	180-210	T 140-160	1-3	4-5	
9			5-7 AC	5-7 AC	

NC means NO CONNECTION
T means used as tiepoint

3. Have a friend check over the wiring. Wiring errors, consistently overlooked by the constructor, may be readily evident to another person.
4. Write to the Heath Company, referring to this instrument as the QM-1 "Q" meter, and describe the difficulty encountered. Include all information that may be helpful in locating the cause, such as voltage readings for instance, and we will attempt to advise you by return mail.
5. Should inspection reveal the necessity for replacement of a component, write to the Heath Company immediately. The following information should be supplied in all cases:

   A. Thoroughly identify the part in question by using the part number and description found in the manual parts list.
   B. Identify the type and model number of kit in which it is used.
   C. Mention the order number and date of purchase.
   D. Describe the nature of defect or reason for requesting replacement.

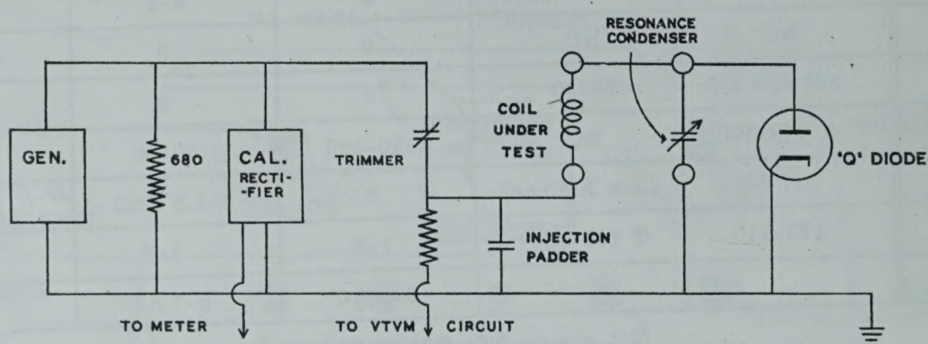
PRINCIPLES OF OPERATION

The Heathkit Q meter operates on the principle of resonance. To obtain this resonance two conditions must be satisfied: 1. There must be a circuit capable of resonance and 2. There must be a signal to which the circuit can resonate. The signal is obtained from the generator section, and the resonant circuit comprises the Resonance condenser, the injection padder condenser and the coil under test.

To indicate resonance, a VTVM circuit is connected across the Resonance condenser. If the current flow from the generator through the injection padder is obtained from a constant current source, the voltage at resonance developed across the coil under test will be directly proportional to the Q of the circuit. Because the injection padder is much larger than the resonance condenser, practically all of the voltage across the coil appears also across the resonance condenser, where it is measured by the VTVM.

When external capacities are connected in parallel with the resonating condenser this may no longer be true and the indicated circuit Q may be much less than the actual circuit Q. (If the external capacity and the resonating condenser total 5000 MMF, the indicated Q will be half the actual Q.)

By making the injection current a constant of a particular value, the voltage developed across the coil will be a direct indication of the Q of the circuit.



To insure a constant injection current, the output from the generator is metered to give a constant voltage. This voltage is applied to a small trimmer condenser in series with the large injection padder. The current depends practically only on the setting of the trimmer condenser and the padder current is constant. Adjustment of the trimmer during calibration correlates the meter readings of the Calibrate and VTVM sections. The relationship is independent of frequency and thus this calibration at one frequency will hold for all others.

Any losses in the resonant circuit will be reflected in a lower Q reading. In general, the losses in the coil are much greater than the losses in the other circuit elements. Thus the Q of the circuit is the Q of the coil for all practical purposes. However, for conditions involving very high Q coils and low capacity settings of the resonating condenser, this may not hold fully true, and the losses in the resonating condenser and the stray capacity reduce the indicated circuit Q below the Q of the coil itself. The effective value of the resonating condenser is used in the tests involving resonance with a coil, and is equal to the capacity of the resonating condenser in series with the injection padder.

The total capacity between the C terminals is the sum of the capacity of the resonating condenser and the stray capacities in the wiring. This value is used in capacity measurements using the substitution method.

APPLICATIONS

The Heathkit Q Meter is an instrument that enables the technician to simulate conditions actually encountered in practical circuits, and measure the performance of the coil or condenser by itself. Such measurements are made at the operating frequency actually encountered in the practical circuits.

Thus, during the design of a broadcast receiver for instance, a loop antenna may be checked for frequency coverage and for loss of Q because of the proximity of the chassis. Various types of loop antennas may be compared by noting the Q indicated. The distributed capacity of the loop may readily be determined. The effective capacity of a tuning condenser, as well as the minimum capacity may be readily determined by substitution.

The following procedures may be used as a guide until sufficient familiarity with the instrument and its characteristics are obtained.

To measure inductance of a coil:

Set the CAL-Q switch to CAL.
Connect the coil to the L terminals.
Set the generator section to the appropriate frequency (250 kc, 790 kc, 2.5 mc or 7.9 mc) and adjust the level to X1.
Set the CAL-Q switch to Q.
Adjust the resonating condenser for maximum indication on the meter.
Read the inductance on the L scale and place the decimal point properly by referring to the inductance-frequency tabulation.

To measure the Q of a coil:

Set the CAL-Q switch to CAL.
Connect the coil to the L terminals.
Set the generator section to the desired frequency, and adjust the level to X1.
Set the CAL-Q switch to Q.
Adjust the resonating condenser accurately for maximum indication on the meter.
Read the Q value on the meter.
(If the meter reads off scale, switch to CAL. and adjust level to X2. Switch to Q and double the indicated value.)

To measure the distributed capacity of a coil:

Set the CAL-Q switch to CAL.
Connect the coil to the L terminals.
Set the resonating condenser to a convenient small value such as 100 MMF (C_E scale). Note this value as C_A.
Set the CAL-Q switch to Q and adjust the generator section to give a maximum indication.
Note the generator frequency.
Set the generator to a new frequency equal to half the old frequency.
Switch to CAL and check the level.
Switch back to Q and adjust the resonating condenser to give a maximum indication.
Note the value on the C_E scale and call this value C_B.
The distributed capacity is readily calculated from

$$C_D = \frac{C_B - 4C_A}{3}$$

Note: While this method is not completely accurate, it will suffice in most cases. The accuracy may be increased by repeating the measurement with different values of C_A and averaging the results.

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To measure a capacity of ~~425~~ MMF or less:

Set the CAL-Q switch to CAL.
Connect a test coil to the L terminals.
Connect the unknown condenser to the C terminals.
Set the resonating condenser to a small value (50 MMF for instance). Note this value as C_A.
Switch to Q and adjust the generator section for maximum indication.
Switch to CAL and remove the unknown condenser.
Switch to Q and adjust the resonating condenser for maximum indication.
Note the reading on the C_T scale as C_B.
The unknown capacity is readily calculated from

$$C_X = C_B - C_A.$$

Note: For very small capacities, the vernier dial may be used instead of the main dial.

To measure a capacity larger than 425 MMF: *

Set CAL-Q switch to CAL.
Connect a test coil of known inductance to the L terminals.
Connect the unknown condenser to the C terminals.
Switch to Q and adjust the generator for maximum reading.
Note the capacity on the C_T scale as C_A.
Note the generator frequency as f.
Using the inductance of the test coil as L, calculate the resonating capacity C_B from

$$C_B = \frac{1}{6.28^2 f^2 L} \qquad \text{i.e. } \omega L = \frac{1}{\omega C_B}$$

This value C_B is made up of three parts: C_A in parallel with the unknown capacity C_X and and the two in series with the 5000 MMF injection padder. The unknown is calculated from

$$C_X = \frac{5000\, C_B}{5000 - C_B} - C_A$$

SERVICE

In event continued operational difficulties of the completed instrument are experienced, may we remind you that the facilities of the Heath Company Service Department are at your disposal. Your instrument may be returned for inspection and repair for a service charge of $5.00 plus the cost of any additional material that may be required. THIS SERVICE POLICY APPLIES ONLY TO COMPLETED INSTRUMENTS CONSTRUCTED IN ACCORDANCE WITH THE INSTRUCTIONS AS STATED IN THE MANUAL. Instruments that are not completed or instruments that are modified will not be accepted for repair. Instruments showing evidence of acid core solder or paste fluxes will be returned NOT repaired.

The Heath Company is willing to offer its utmost cooperation to assist you in obtaining the proper operation of your instrument and therefore the factory repair service is available for a period of one year from the date of purchase.

NOTE: Before returning this unit, be sure that all parts are securely mounted. Attach a tag to the instrument, giving name, address and trouble experienced. Pack in a rugged container, preferably wood, using at least three inches of shredded newspaper or excelsior on all sides. Do not ship in the original kit carton as this carton is not considered adequate for safe shipment of the completed instrument. Ship by prepaid express, if possible. Return shipment will be made by express collect. Note that a carrier cannot be held liable for damages in transit if PACKING IN HIS OPINION is insufficient.

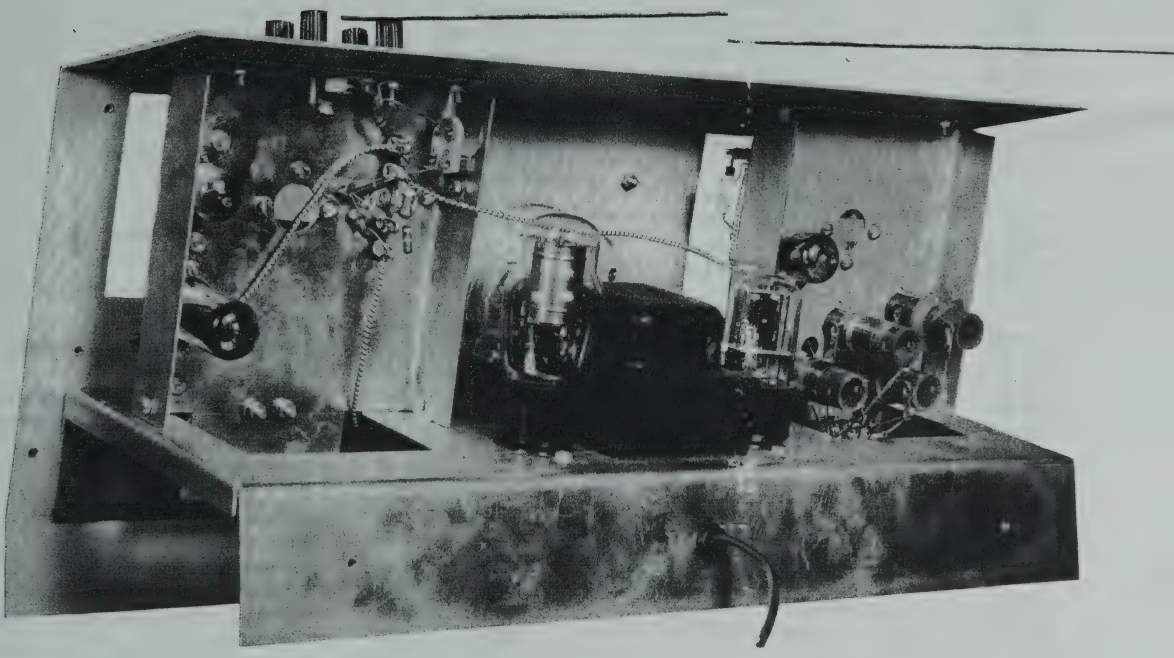
Prices are subject to change without notice. The Heath Company reserves the right to change the design of this instrument without incurring liability for equipment previously supplied.

WARRANTY

The Heath Company limits its warranty of any parts supplied with any Heathkit (except tubes, meters and rectifiers, where the original manufacturer's guarantee only applies) to the replacement within three (3) months of said part, which when returned with prior permission, postpaid, was, in the judgment of the Heath Company, defective at the time of sale.

The assembler is urged to follow the instructions exactly as provided. The Heath Company assumes no responsibility or liability for any damages or injuries sustained in the assembly of the device or in the operation of the completed instrument.

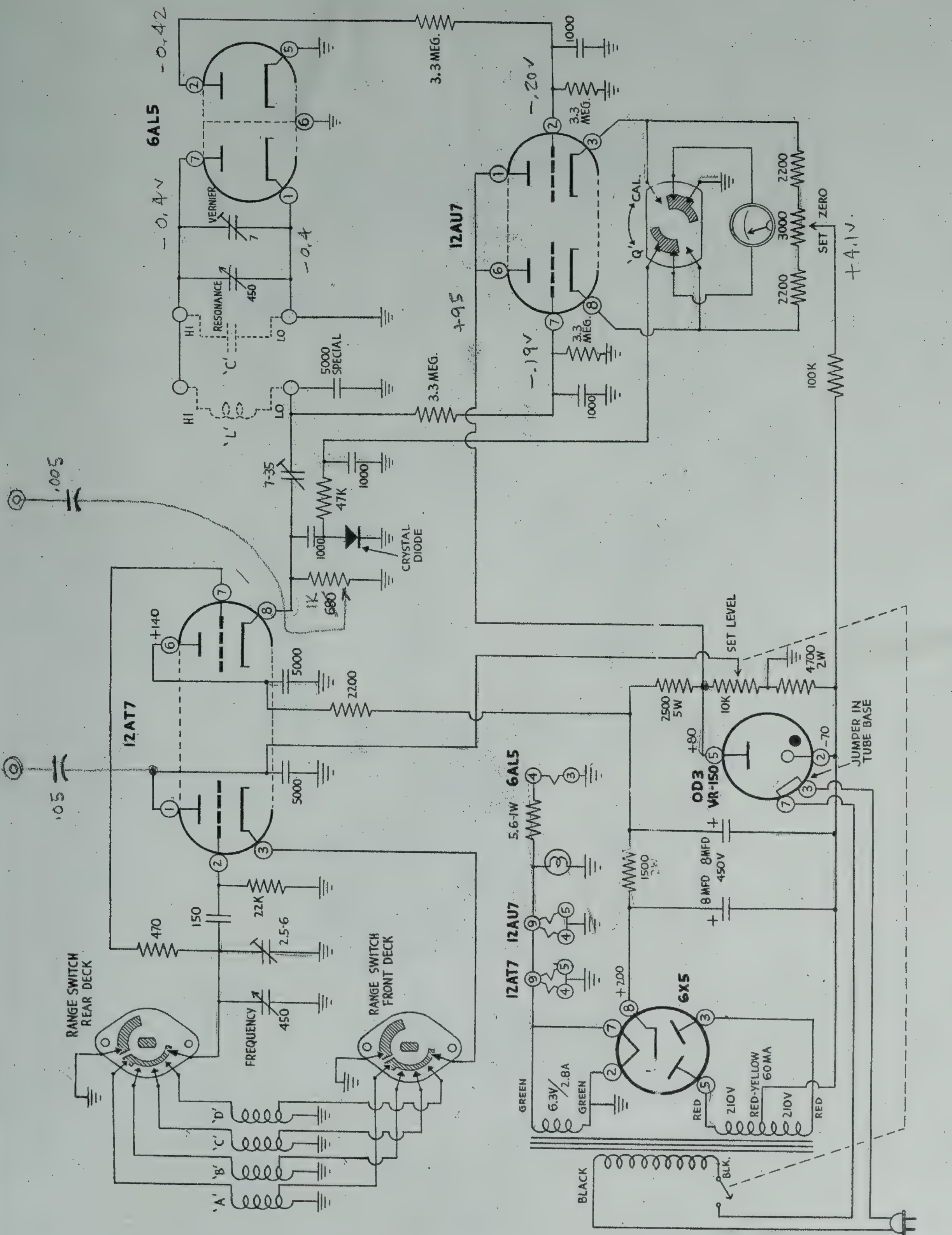
HEATH COMPANY
Benton Harbor, Michigan



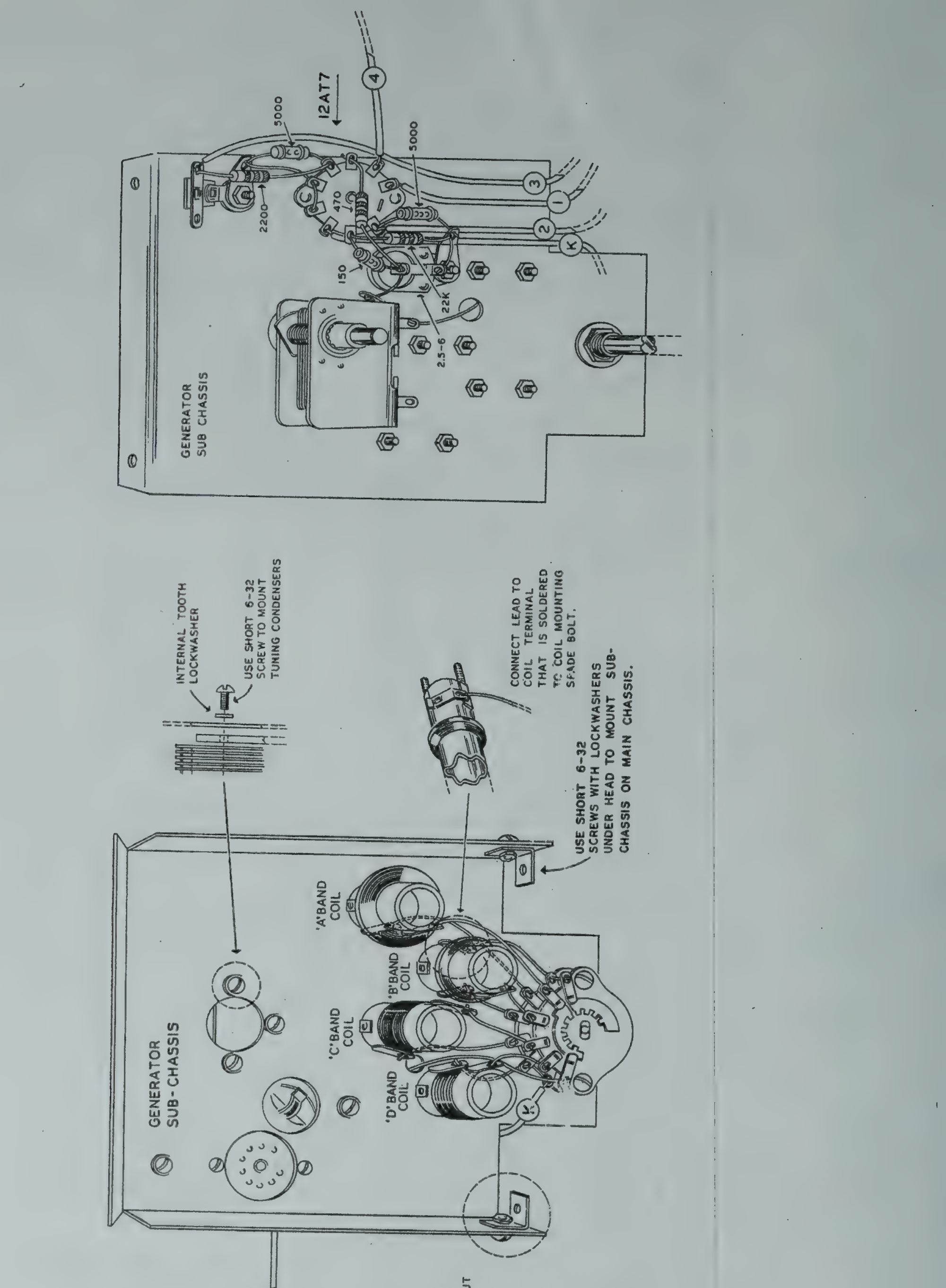
PARTS LIST

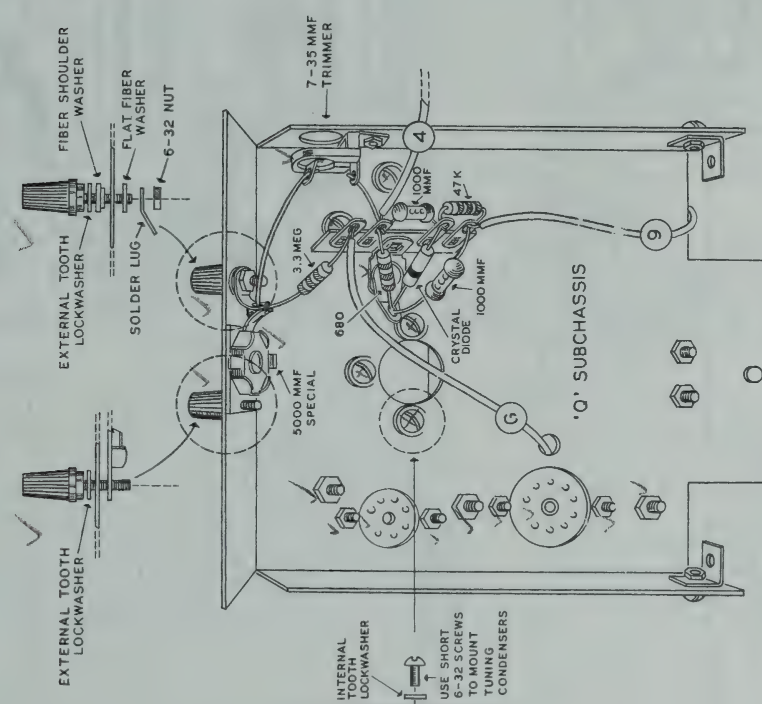
Part No.	Parts Per Kit	Description
Resistors		
1-6	1	470 Ohms
1-7	1	680 Ohms
1-44	3	2200 Ohms
1-22	1	22K Ohms
1-25	1	47K Ohms
1-26	1	100K Ohms
1-38	4	3.3 Meg. Ohms
1-41A	1	5.6 Ohm 1 watt
1-14B	1	1500 Ohm 2 watt
1-2B	1	4700 Ohm 2 watt
3-1E	1	2500 Ohm 5 watt
Controls		
11-9	1	3000 Ohms w.w.
19-2	1	10K Ohms w. switch
Condensers		
20-26	1	5000 MMF special
21-11	1	150 MMF
21-14	4	1000 MMF
21-15	2	5000 MMF
25-3	1	8 + 8 MFD 450 volt
26-11	2	450 MMF tuning
26-12	1	7 MMF tuning
31-7	1	2.5-6 MMF
31-5	1	7-35 MMF
Coils		
40-11	1	Band "A" coil
40-12	1	Band "B" coil
40-13	1	Band "C" coil
40-14	1	Band "D" coil
40-23	1	Test coil
Transformer—Crystal—Switches		
54-5	1	Power transformer
56-1	1	Crystal diode
63-48	1	4-position switch
63-49	1	DPDT—NS switch
Wire		
89-1	1	Line cord
212-M2	1	Brass strip
340-2	1	Length bare wire
344-1	1	Length hookup wire
346-1	1	Length sleeving
349-1	1	Length dial cord
Knobs—Pilot light parts		
462-4	1	Acorn knob
462-6	2	Tuning knobs
462-M11	4	Pointer knobs
100-M10	2	Dial pointers
252-12	1	Pilot light nut
413-1	1	Pilot light jewel
434-22	1	Pilot light socket
455-1	1	Pilot light bushing

Part No.	Parts Per Kit	Description
Sockets—Terminals		
434-2	2	Octal sockets
434-16	2	Noval 9-pin sockets
434-34	1	Miniature 7-pin socket
427-2	4	Terminal bases
100-M16	4	Terminal caps
75-9	1	Terminal insulator strip
431-1	1	1-lug terminal strip
431-3	1	3-lug terminal strip
431-5	2	4-lug terminal strips
Meter—Tubes—Lamp		
407-17	1	50 microamp. meter
411-17	1	6X5 tube
411-24	1	12AT7 tube
411-25	1	12AU7 tube
411-32	1	OD3/VR150 tube
411-40	1	6AL5 tube
412-1	1	#47 lamp
Metal Parts		
90-18	1	Cabinet
100-M19	2	Dial drive pulleys
200-M40	1	Chassis
200-M41	1	Gen. subchassis
200-M42	1	"Q" subchassis
203-M41F31	1	Panel
204-M42	1	Drive Shaft bracket
205-M17F33	1	Gen. dial plate
205-M17F34	1	"Q" dial plate
205-M18	1	Assembly template
453-M6	1	Drive shaft
Hardware		
250-2	6	3-48 screws
250-7	17	6-32 x 3/16 screws
250-8	17	#6 x 3/8 Sheet metal screws
250-9	18	6-32 x 3/8 screws
250-15	2	8-32 x 1/8 pointer set screws
250-16	2	8-32 x 3/16 pulley set screws
250-22	4	8-32 knob set screws
252-1	6	3-48 nuts
252-3	33	6-32 nuts
252-4	2	8-32 nuts
252-7	4	Control nuts
253-1	1	#6 flat fiber washer
253-2	1	#6 Fiber shoulder washer
253-10	3	Control nickel washers
253-11	1	"E" washer
254-1	37	#6 lockwashers (int.)
254-2	2	#8 lockwashers
254-5	4	Control lockwashers
254-6	4	#6 lockwashers (ext.)
254-7	6	#3 lockwashers
259-1	9	#6 solder lugs
73-1	2	3/8 rubber grommets
204-9	4	Angle brackets
258-1	1	Dial cord spring
261-1	4	Rubber feet

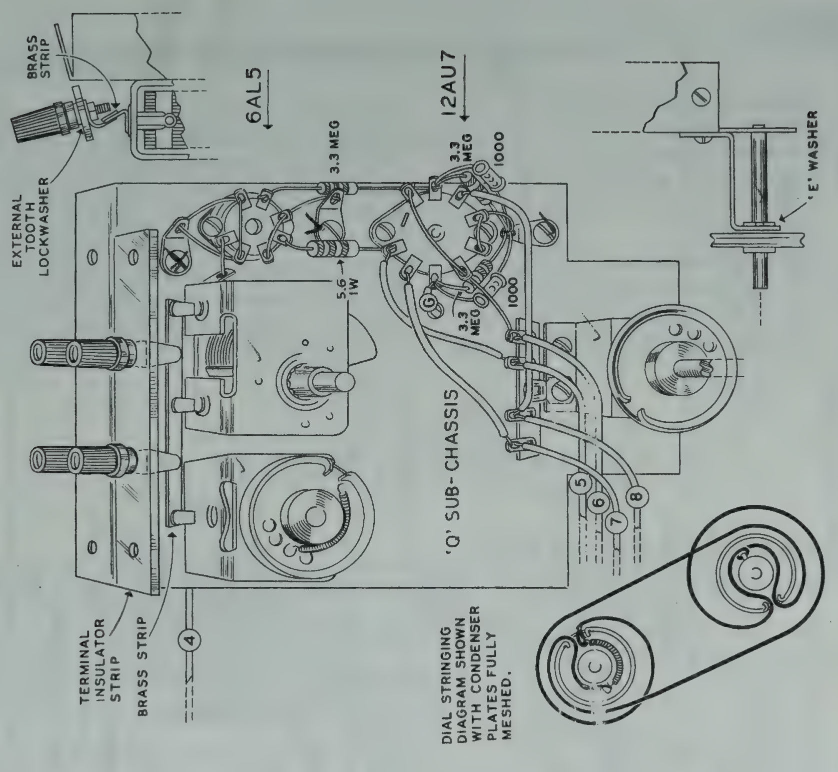


6AL5
3.3 MEG.
1000
-0.42
-0.4V
-.20V
3.3 MEG.
VERNIER
RESONANCE
450
HI
LO
'C'
-0.4
12AU7
2200
3000
2200
CAL.
'Q'
SET ZERO
+4.1V
+95
-.19V
3.3 MEG.
5000 SPECIAL
'L'
1000
100K
.005
7-35
47K
1000
CRYSTAL DIODE
1K
680
+140
12AT7
5000
2200
SET LEVEL
4700 2W
10K
2500 5W
+80
-70
JUMPER IN TUBE BASE
OD3 VR-150
IN
.05
5000
6AL5
5.6-1W
12AU7
12AT7
1500
8 MFD 8MFD 450V
470
150
22K
2.5-6
FREQUENCY
450
RANGE SWITCH REAR DECK
RANGE SWITCH FRONT DECK
+200
6X5
'A'
'B'
'C'
'D'
GREEN
6.3V/2.8A
GREEN
RED
210V
RED-YELLOW 60MA
210V
RED
BLACK
BLK.

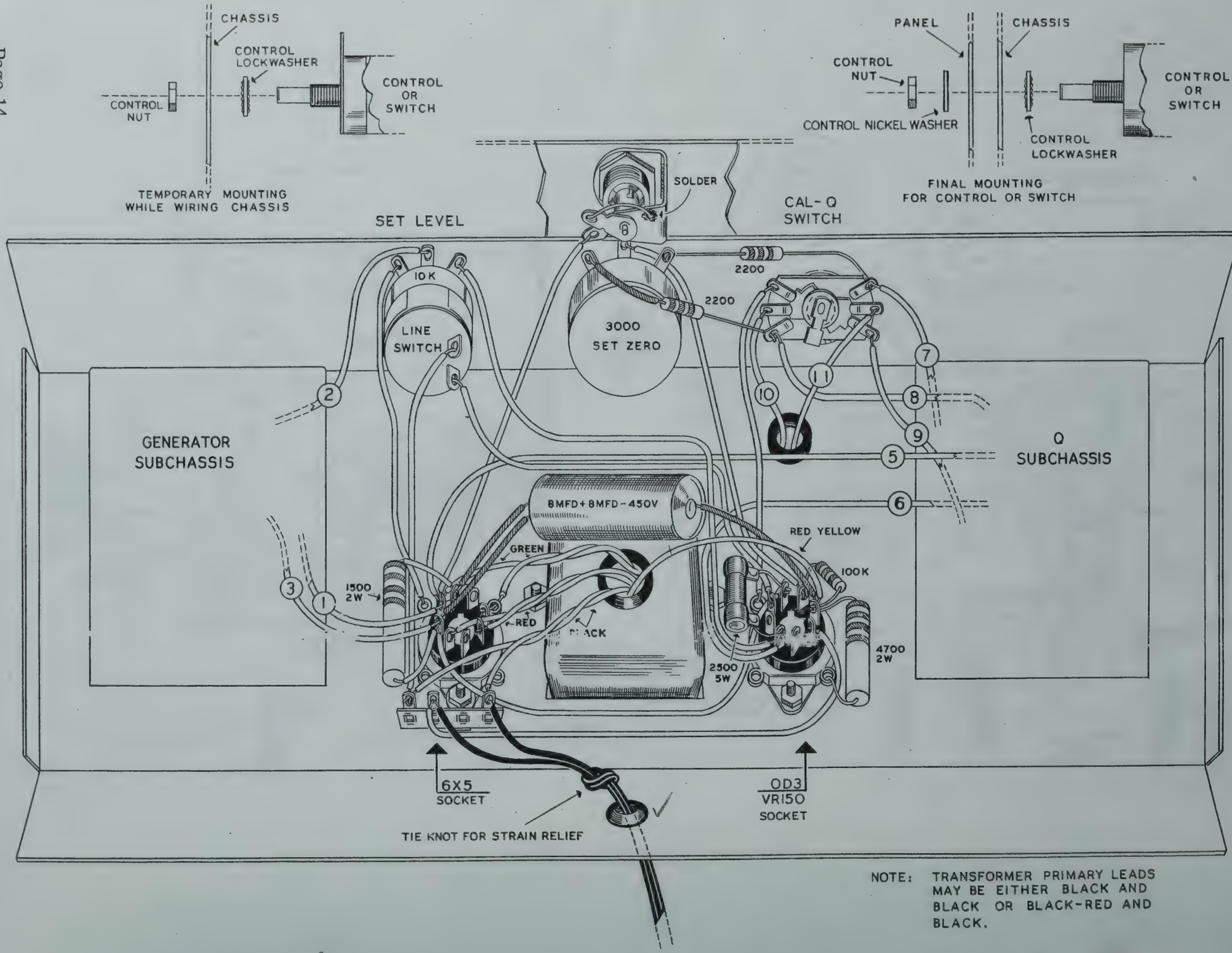

12AT7
5000
5000
2200
470
150
22K
2.5-6
GENERATOR
SUB CHASSIS
INTERNAL TOOTH
LOCKWASHER
USE SHORT 6-32
SCREW TO MOUNT
TUNING CONDENSERS
CONNECT LEAD TO
COIL TERMINAL
THAT IS SOLDERED
TO COIL MOUNTING
SPADE BOLT.
USE SHORT 6-32
SCREWS WITH LOCKWASHERS
UNDER HEAD TO MOUNT SUB-
CHASSIS ON MAIN CHASSIS.
GENERATOR
SUB-CHASSIS
'A'BAND
COIL
'B'BAND
COIL
'C'BAND
COIL
'D'BAND
COIL
6-32 NUT
INTERNAL TOOTH
LOCKWASHER
SHORT 6-32 SCREW



EXTERNAL TOOTH LOCKWASHER
EXTERNAL TOOTH LOCKWASHER
FIBER SHOULDER WASHER
FLAT FIBER WASHER
6-32 NUT
SOLDER LUG
7-35 MMF TRIMMER
3.3 MEG
1000 MMF
47 K
680
CRYSTAL DIODE
1000 MMF
5000 MMF SPECIAL
'Q' SUBCHASSIS
G
4
9
INTERNAL TOOTH LOCKWASHER
USE SHORT 6-32 SCREWS TO MOUNT TUNING CONDENSERS



BRASS STRIP
EXTERNAL TOOTH LOCKWASHER
6AL5
12AU7
3.3 MEG
3.3 MEG
1000
5.6 1W
3.3 MEG
1000
G
TERMINAL INSULATOR STRIP
BRASS STRIP
4
5
6
7
8
'Q' SUB-CHASSIS
'E' WASHER
DIAL STRINGING DIAGRAM SHOWN WITH CONDENSER PLATES FULLY MESHED.



NOTE: TRANSFORMER PRIMARY LEADS MAY BE EITHER BLACK AND BLACK OR BLACK-RED AND BLACK.

9. Read the resistance, indicated by the dial pointer, on the "B" scale. If the dial pointer indicates "1" (center scale), the resistors are of equal value. If the pointer is to the right or left of center scale, the resistors are not of equal value. To determine the value of the unequal resistor (or any component being tested), use the formulas shown inside the "B" scale. If the pointer is to the left of center scale, use the formulas inside the left scale. If the pointer is to the right of center scale, use the formulas inside the right scale. It is normal when you measure extreme values, to have the null occur at a much higher point on the null meter.

NOTE: If you use batteries with your RLC Bridge, measure them with a voltmeter occasionally to make sure they are 7 volts or higher. This will insure the best operation for your bridge.

IN CASE OF DIFFICULTY

This part of the Manual provides you with information that will help you locate and correct difficulties which may occur in your RLC Bridge. This information is divided into two sections. The first section, "General," contains suggestions of a general nature in the following areas:

- Visual check and inspection.
- Precautions to observe when bench testing.

The second section contains a "Troubleshooting Chart" that has a series of "Conditions" and "Possible Causes." Start your troubleshooting procedure by first reading the following "General" section. Then proceed to the appropriate "Condition" and "Possible Cause."

GENERAL

Visual Checks

1. About 90% of the kits that are returned for repair do not function properly due to poor soldering. Therefore, you can eliminate many troubles by a careful inspection of connections to make sure they are soldered as described in the "Soldering" section of the "Assembly Notes." Re-heat any doubtful connections and be sure all the wires are soldered at places where several wires are connected. Check carefully for solder bridges between circuit board foils.

2. Check to be sure that all transistors are in their proper locations, and are installed correctly.

3. Check the value of each part. Be sure that the proper part has been wired into the circuit, as shown in the Pictorial diagrams and is called out in the wiring instructions. It would be easy, for example,to install a 200 Ω (red-black-brown) resistor in a step that calls for a 1000 Ω (brown-black-red) resistor.

4. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as you check it. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something you have consistently overlooked.

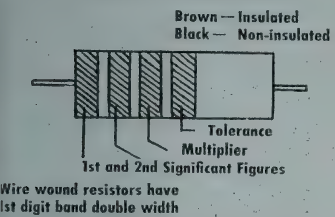
5. Check all component leads connected to the circuit board. Make sure the leads do not extend too far through the circuit board and make contact with other connections or parts.

6. Check all of the wires that are connected to the circuit board or switches to be sure the wires do not touch each other or other lugs. Make sure all wires are properly soldered.

7. If the difficulty still is not cured, read the "Precautions for Bench Testing," then refer to the "Troubleshooting Chart."

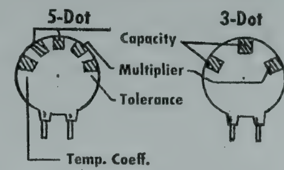
STANDARD COLOR CODE — RESISTORS AND CAPACITORS

AXIAL LEAD RESISTOR

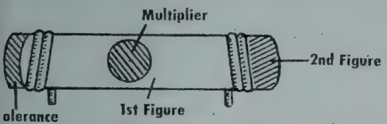


INSULATED UNINSULATED Color	FIRST RING BODY COLOR First Figure	SECOND RING END COLOR Second Figure	THIRD RING DOT COLOR Multiplier
BLACK	0	0	None
BROWN	1	1	0
RED	2	2	00
ORANGE	3	3	,000
YELLOW	4	4	0,000
GREEN	5	5	00,000
BLUE	6	6	000,000
VIOLET	7	7	0,000,000
GRAY	8	8	00,000,000
WHITE	9	9	000,000,000

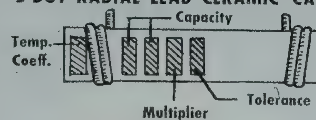
DISC CERAMIC RMA CODE



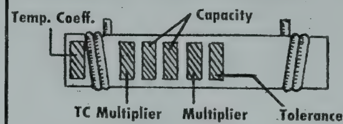
RADIAL LEAD DOT RESISTOR



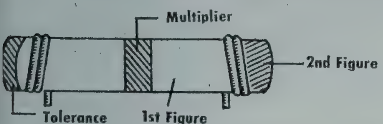
5-DOT RADIAL LEAD CERAMIC CAPACITOR



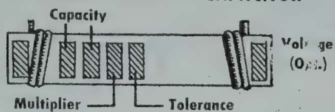
EXTENDED RANGE TC CERAMIC HICAP



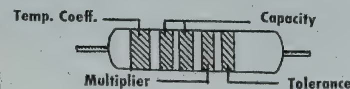
RADIAL LEAD (BAND) RESISTOR



BY-PASS COUPLING CERAMIC CAPACITOR



AXIAL LEAD CERAMIC CAPACITOR

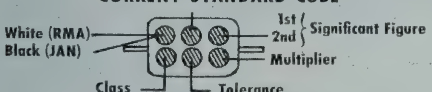


The standard color code provides all necessary information required to properly identify color coded resistors and capacitors. Refer to the color code for numerical values and the zeroes or multipliers assigned to the colors used. A fourth color band on resistors determines tolerance rating as follows: Gold = 5%, silver = 10%. Absence of the fourth band indicates a 20% tolerance rating.

The physical size of carbon resistors is determined by thei wattage rating. Carbon resistors most commonly used in Heath kits are ½ watt. Higher wattage rated resistors when specifie are progressively larger in physical size. Small wire woun resistors ½ watt, 1 or 2 watt may be color coded but the firs band will be double width.

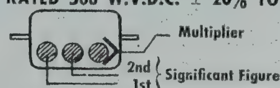
MOLDED MICA TYPE CAPACITORS

CURRENT STANDARD CODE



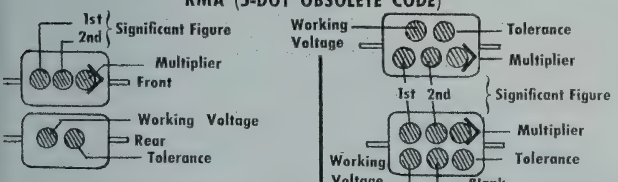
JAN & 1948 RMA CODE

RMA 3-DOT (OBSOLETE) RATED 500 W.V.D.C. ± 20% TOL.

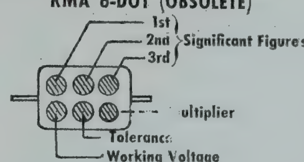


BUTTON SILVER MICA CAPACITOR

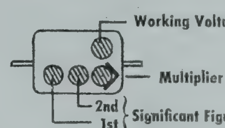
RMA (5-DOT OBSOLETE CODE)



RMA 6-DOT (OBSOLETE)

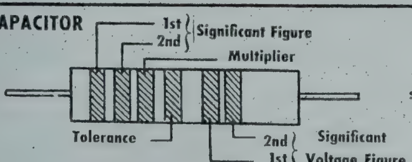


RMA 4-DOT (OBSOLETE)



MOLDED PAPER TYPE CAPACITORS

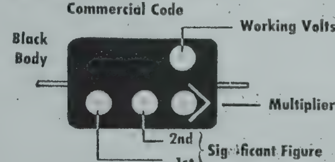
TUBULAR CAPACITOR



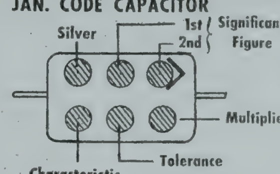
A 2 digit voltage rating indicates more than 900 V. Add 2 zeros to end of 2 digit number.

MOLDED FLAT CAPACITOR

Commercial Code



JAN. CODE CAPACITOR



The tolerance rating of capacitors is determined by the color code. For example: red = 2%, green = 5%, etc. The voltage rating of capacitors is obtained by multiplying the color value by 100. For example: orange = 3 × 100 or 300 volts. Blue = 6 × 100 or 600 volts.

In the design of Heathkits, the temperature coefficient of ceramic or mica capacitors is not generally a critical factor and therefore Heathkit manuals avoid reference to temperature coefficient specifications.

Courtesy of Centralc

PRICE $1.00

CONDENSED

Assembling and Using Your... Heathkit

Q-METER

MODEL QM-1

HEATH COMPANY

A Subsidiary of Daystrom Inc.

BENTON HARBOR, MICHIGAN

5-52

Assembling and Using Your...

Heathkit

Q-METER

MODEL QM-1

HEATH COMPANY

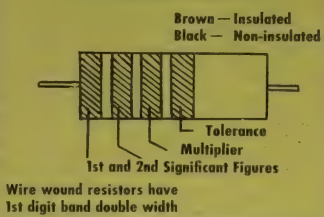
A Subsidiary of Daystrom Inc.

BENTON HARBOR, MICHIGAN

595-52

STANDARD COLOR CODE — RESISTORS AND CAPACITORS

AXIAL LEAD RESISTOR



INSULATED UNINSULATED Color	FIRST RING BODY COLOR First Figure	SECOND RING END COLOR Second Figure	THIRD RING DOT COLOR Multiplier
BLACK	0	0	None
BROWN	1	1	0
RED	2	2	00
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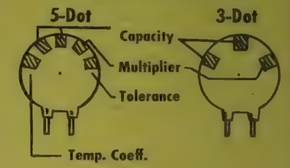
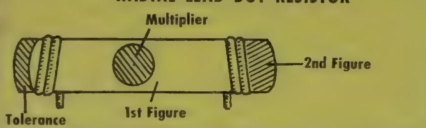
YELLOW	4	4	0,000
GREEN	5	5	00,000
BLUE	6	6	000,000
VIOLET	7	7	0,000,000
GRAY	8	8	00,000,000
WHITE	9	9	000,000,000

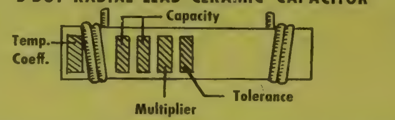
DISC CERAMIC RMA CODE



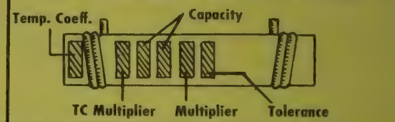
RADIAL LEAD DOT RESISTOR



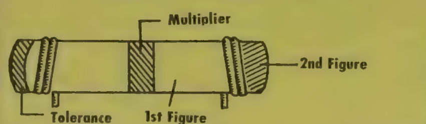
5-DOT RADIAL LEAD CERAMIC CAPACITOR



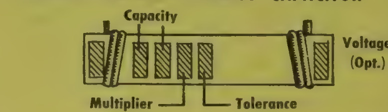
EXTENDED RANGE TC CERAMIC HICAP



RADIAL LEAD (BAND) RESISTOR



BY-PASS COUPLING CERAMIC CAPACITOR



AXIAL LEAD CERAMIC CAPACITOR

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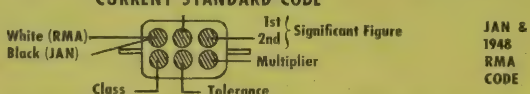
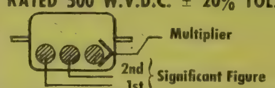
MOLDED MICA TYPE CAPACITORS

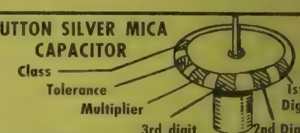
CURRENT STANDARD CODE



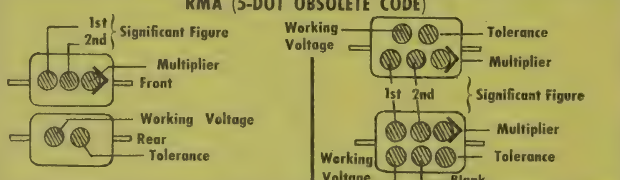
RMA 3-DOT (OBSOLETE) RATED 500 W.V.D.C. ± 20% TOL.



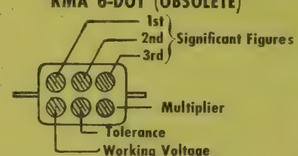
BUTTON SILVER MICA CAPACITOR



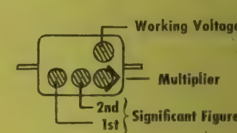
RMA (5-DOT OBSOLETE CODE)



RMA 6-DOT (OBSOLETE)

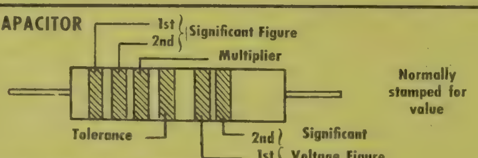


RMA 4-DOT (OBSOLETE)



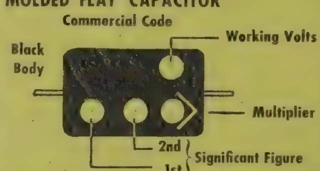
MOLDED PAPER TYPE CAPACITORS

TUBULAR CAPACITOR

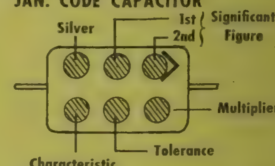


A 2 digit voltage rating indicates more than 900 V.
Add 2 zeros to end of 2 digit number.

MOLDED FLAT CAPACITOR



JAN. CODE CAPACITOR

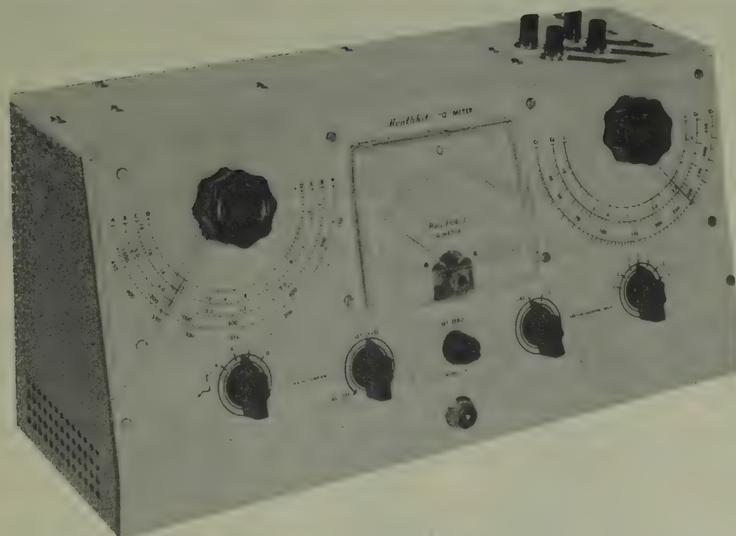


The tolerance rating of capacitors is determined by the color code. For example: red = 2%, green = 5%, etc. The voltage rating of capacitors is obtained by multiplying the color value by 100. For example: orange = 3 × 100 or 300 volts. Blue = 6 × 100 or 600 volts.

In the design of Heathkits, the temperature coefficient of ceramic or mica capacitors is not generally a critical factor and therefore Heathkit manuals avoid reference to temperature coefficient specifications.

Courtesy of Centralab

HEATHKIT
MODEL QM-1
Q-METER



SPECIFICATIONS

Power Requirements	115 volts AC 50/60 cycles 30 watts
Tube Complement	1 - 12AT7 Oscillator
	1 - 6AL5 VTVM diode
	1 - 12AU7 VTVM amplifier
	1 - OD3/VR150 Regulator
	1 - 6X5 Rectifier
Frequency Range	150 KC - 18 MC
Inductance Scale Range	1 micro H. - 10 milli H.
Actual Capacity Scale Range	40 MMF - 450 MMF
Effective Capacity Scale Range	40 MMF - 400 MMF
Vernier Capacity Scale Range	-3 MMF - +3 MMF
"Q" Scale Range	250 Full scale x1 or x2
Dimensions	8" high x 17" wide x 6" deep

ASSEMBLY AND OPERATION OF THE
HEATHKIT MODEL QM-1 Q-METER

The Heathkit Q Meter is a device of particular value in work with resonant circuits within the frequency and capacity ranges of the instrument.

It enables the user to measure the performance of such circuits and their component parts at the operating frequency and thus makes it possible to predict their operation in actual use.

The instrument is designed for simplicity both in construction and operation. But despite its simplicity, it is capable of excellent performance if properly constructed and intelligently used. Care used in the assembly will reward the builder through years of reliable service. Maximum results will be obtained by following the information given in this manual. It is, therefore, suggested that you take a few minutes now and read the entire manual, or at least the parts pertaining to the assembly and testing before any work is started.

Large pictorial diagrams are furnished and should be attached above the work space for your convenience. These pictorials are duplicated in a smaller size in this manual. The large prints may be discarded after the instrument is completed, but the manual should be retained in your files for future reference.

Unpack the kit carefully and check each part against the parts list. In doing this, you will become acquainted with each part. Refer to the charts and other information on the inside covers of this manual to help you identify any parts about which there may be a question. Make sure that all parts have been removed from the packaging material before it is thrown out. If a shortage is found in checking the parts, please notify us promptly and return the inspection slip with your letter to us. Hardware items are counted by weight, and if a few are missing, please obtain them locally if at all possible.

Resistors and controls generally have a tolerance rating of plus or minus 20% unless otherwise stated in the parts list. Thus a 10,000 ohm resistor may test anywhere from 8,000 ohms to 12,000 ohms. The tolerance on condensers is frequently even greater. This Heathkit is designed to accommodate such variations.

Small changes in parts may be made by the Heath Company. Such changes will not adversely affect the operation of the instrument, and will only be made to insure a minimum delay in filling your order.

Read the note on soldering on the inside back cover. Use only good quality rosin core radio type solder. Pastes or acids, while making soldering even easier, do not result in a joint satisfactory for radio work. Their cleaning action is based on a corroding effect, even if they are called "non-corrosive." They are very difficult to remove completely after the joint is made, and even a minute quantity left behind combines with moisture in the air to form a highly corrosive and conductive product. Thus weeks or months later the continued corrosion may "eat up" the wire or the joint causing failure through open circuits, or the conduction through the growing deposit may cause sufficient leakage to prevent proper operation.

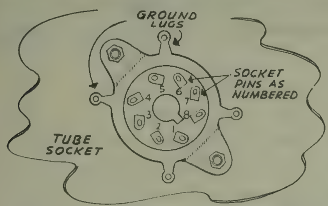
NOTE: All guarantees are voided and we will not repair or service instruments in which acid core solder or pastes are used. (When in doubt about solder, it is recommended that a new roll plainly marked "Rosin Core Radio Solder" be purchased.)

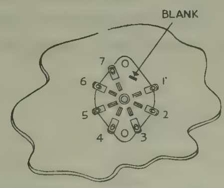
CONSTRUCTION

Many components are supplied by the manufacturers with leads that are longer than the particular application requires. Of course, all excess lead lengths should be removed so as to permit neat and direct installation of the components involved. Following this procedure will very definitely result in superior operation of the instrument and will afford you a sense of satisfaction and pride in having constructed a neat and professional appearing instrument.

Whenever necessary, use spaghetti or insulated sleeving over bare wires on condensers or resistors to prevent the leads from accidentally touching adjacent terminals, wires or metal parts.

Assemble the generator sub-chassis, the "Q" sub-chassis, the main chassis and the panel separately. Wire the first three parts as far as possible, then mount both sub-chassis on the main chassis and complete the wiring between these parts. Attach the panel to the chassis and complete the wiring.

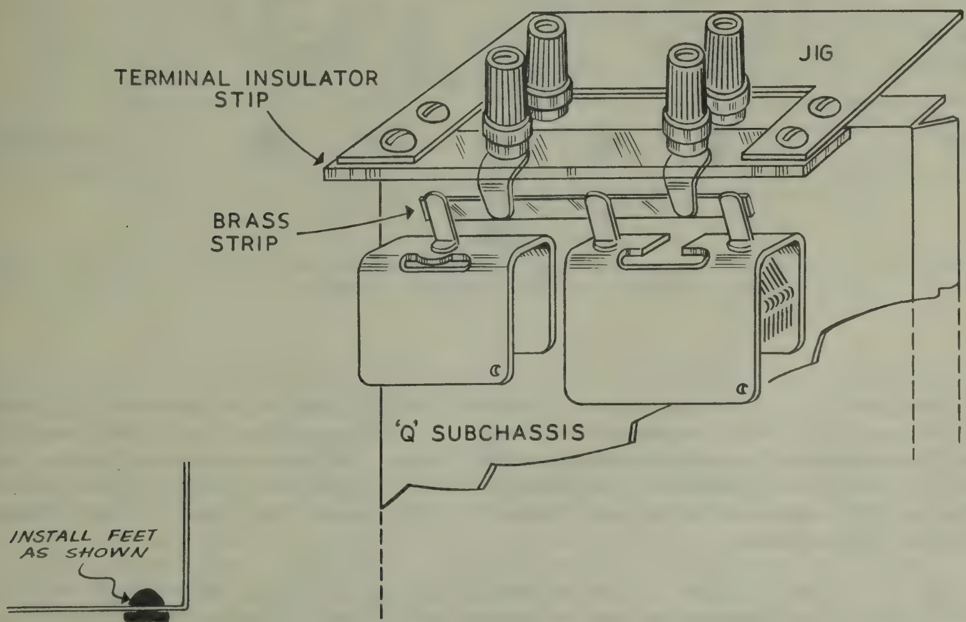




PIN NUMBERING ON MINIATURE TUBE SOCKET

PIN NUMBERING ON NOVAL TUBE SOCKET

Note: Make sure the miniature and noval tube sockets are free from obstructions before inserting the tubes. These small tubes are fairly fragile and broken tubes are not covered by any guarantee.



NOTE: After the tuning condensers are mounted on the "Q" sub-chassis, temporarily fasten the jig to the "Q" sub-chassis and to the insulated terminal strip (with the binding posts attached). Solder the brass strip to the terminal strip solder lugs and the lugs on the tuning condensers. Now the jig can be removed and discarded.

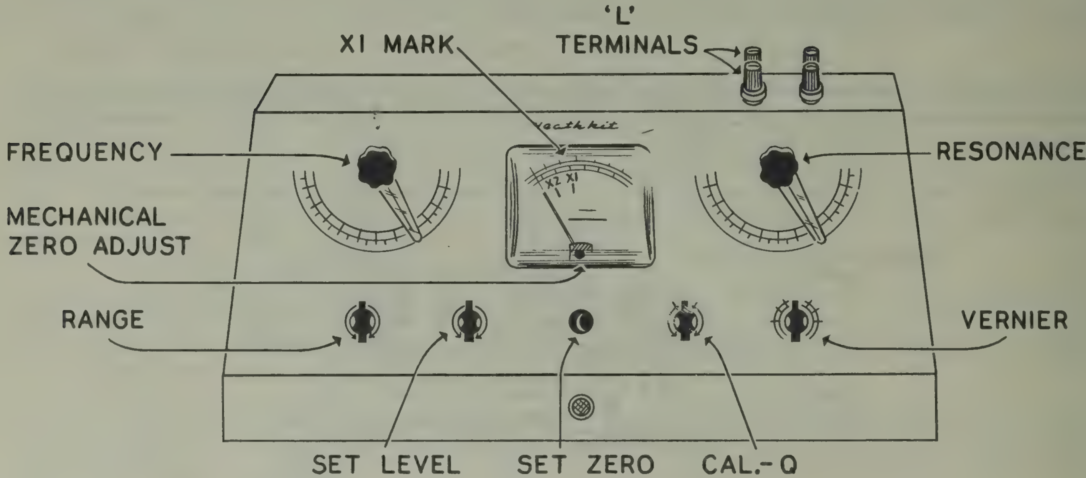
TEST AND CALIBRATION

Check the wiring carefully before proceeding. Inspect all solder connections and make sure that no stray wires or excess solder can cause short circuits between adjacent contacts on sockets and switches.

Plug the line cord into a 117 volt 50-60 cycle AC outlet. CAUTION: Do not connect to a DC outlet for this will seriously damage the power transformer.

Set the CAL-Q switch to CAL and turn the SET LEVEL control clockwise. After a minute warmup observe that the level can be set to the red X1 mark on the meter. Turn the generator RANGE switch and FREQUENCY control to make sure that the X1 reading can be obtained at all frequencies.

Insert the test coil in the "L" terminals. Set the CAL-Q switch to Q and adjust the SET ZERO control for a zero reading on the meter. Set generator section to 1,000 kc and check the level by turning the switch to CAL. Switch back to Q and adjust RESONANCE control for maximum meter reading.



Calibrate the generator section as follows: Tune in a local broadcast station with a frequency between 1200 and 1500 kc on a receiver placed near the Q meter. Set the RANGE switch and FREQUENCY control to the same frequency as the station. With a non-metallic screw driver adjust the trimmer on the generator sub-chassis for the lowest frequency audible beat (zero beat). Now the calibration should be well within 3 percent on all four ranges. This completes the calibration of this section.

Calibrate the Q section as follows: Turn the instrument off and set the mechanical zero-adjust screw on the meter case until the pointer accurately reads zero. Turn the instrument on again. Set the generator section to 1,000 kc and adjust the level to the X1 mark. Switch to Q and turn RESONANCE control for maximum indication. With a non-metallic screw driver adjust the trimmer on the Q sub-chassis until the meter reads the Q value indicated on the test coil. Set the VERNIER to O and adjust the pointer on the shaft of the RESONANCE control to read on the C_E scale the capacity indicated on the test coil. This completes the calibration.

IN CASE OF DIFFICULTY

If the instrument fails to perform as outlined in the foregoing section, proceed as follows:

1. Read the next section entitled "Principles of Operation." A thorough understanding of the circuits used may reveal the cause for difficulties.
2. Check the voltages at the tube sockets and compare them with representative readings tabulated below. Substantial deviation from the tabulated values would point to a particular portion of the circuit. Further investigation of that portion may reveal the cause.

	VOLTAGE TABLE				
	6X5	OD3	12AT7	12AU7	6AL5
1	NC	T 1-4	0-80	70-90	0
2	0	60-80 NEG	0-5 NEG	0-1.5 NEG	0-1.5 NEG
3	200-220 AC	Line Jumper	0	4-5	0
4	NC	NC	0	0	4-6 AC
5	200-220 AC	70-90	0	0	0
6	T 140-160	NC	120-150	70-90	0
7	5-7 AC	Line Jumper	0	0-1.5 NEG	0-1.5 NEG
8	180-210	T 140-160	1-3	4-5	
9			5-7 AC	5-7 AC	

NC means NO CONNECTION
T means used as tiepoint

3. Have a friend check over the wiring. Wiring errors, consistently overlooked by the constructor, may be readily evident to another person.
4. Write to the Heath Company, referring to this instrument as the QM-1 "Q" meter, and describe the difficulty encountered. Include all information that may be helpful in locating the cause, such as voltage readings for instance, and we will attempt to advise you by return mail.
5. Should inspection reveal the necessity for replacement of a component, write to the Heath Company immediately. The following information should be supplied in all cases:

   A. Thoroughly identify the part in question by using the part number and description found in the manual parts list.
   B. Identify the type and model number of kit in which it is used.
   C. Mention the order number and date of purchase.
   D. Describe the nature of defect or reason for requesting replacement.

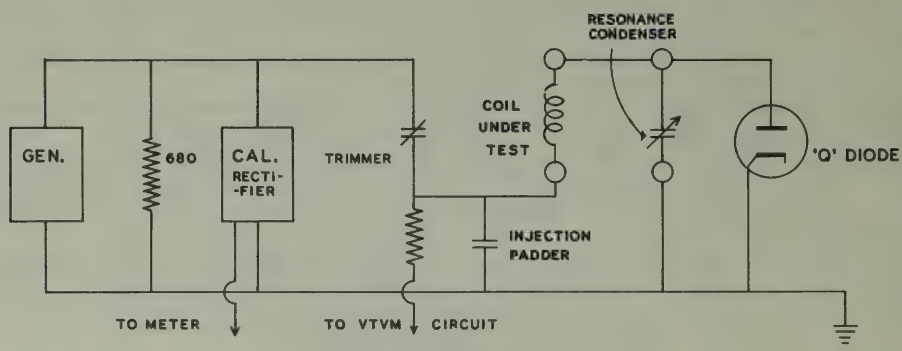
PRINCIPLES OF OPERATION

The Heathkit Q meter operates on the principle of resonance. To obtain this resonance two conditions must be satisfied: 1. There must be a circuit capable of resonance and 2. There must be a signal to which the circuit can resonate. The signal is obtained from the generator section, and the resonant circuit comprises the Resonance condenser, the injection padder condenser and the coil under test.

To indicate resonance, a VTVM circuit is connected across the Resonance condenser. If the current flow from the generator through the injection padder is obtained from a constant current source, the voltage at resonance developed across the coil under test will be directly proportional to the Q of the circuit. Because the injection padder is much larger than the resonance condenser, practically all of the voltage across the coil appears also across the resonance condenser, where it is measured by the VTVM.

When external capacities are connected in parallel with the resonating condenser this may no longer be true and the indicated circuit Q may be much less than the actual circuit Q. (If the external capacity and the resonating condenser total 5000 MMF, the indicated Q will be half the actual Q.)

By making the injection current a constant of a particular value, the voltage developed across the coil will be a direct indication of the Q of the circuit.



To insure a constant injection current, the output from the generator is metered to give a constant voltage. This voltage is applied to a small trimmer condenser in series with the large injection padder. The current depends practically only on the setting of the trimmer condenser and the padder current is constant. Adjustment of the trimmer during calibration correlates the meter readings of the Calibrate and VTVM sections. The relationship is independent of frequency and thus this calibration at one frequency will hold for all others.

Any losses in the resonant circuit will be reflected in a lower Q reading. In general, the losses in the coil are much greater than the losses in the other circuit elements. Thus the Q of the circuit is the Q of the coil for all practical purposes. However, for conditions involving very high Q coils and low capacity settings of the resonating condenser, this may not hold fully true, and the losses in the resonating condenser and the stray capacity reduce the indicated circuit Q below the Q of the coil itself. The effective value of the resonating condenser is used in the tests involving resonance with a coil, and is equal to the capacity of the resonating condenser in series with the injection padder.

The total capacity between the C terminals is the sum of the capacity of the resonating condenser and the stray capacities in the wiring. This value is used in capacity measurements using the substitution method.

APPLICATIONS

The Heathkit Q Meter is an instrument that enables the technician to simulate conditions actually encountered in practical circuits, and measure the performance of the coil or condenser by itself. Such measurements are made at the operating frequency actually encountered in the practical circuits.

Thus, during the design of a broadcast receiver for instance, a loop antenna may be checked for frequency coverage and for loss of Q because of the proximity of the chassis. Various types of loop antennas may be compared by noting the Q indicated. The distributed capacity of the loop may readily be determined. The effective capacity of a tuning condenser, as well as the minimum capacity may be readily determined by substitution.

The following procedures may be used as a guide until sufficient familiarity with the instrument and its characteristics are obtained.

To measure inductance of a coil:

Set the CAL-Q switch to CAL.
Connect the coil to the L terminals.
Set the generator section to the appropriate frequency (250 kc, 790 kc, 2.5 mc or 7.9 mc) and adjust the level to X1.
Set the CAL-Q switch to Q.
Adjust the resonating condenser for maximum indication on the meter.
Read the inductance on the L scale and place the decimal point properly by referring to the inductance-frequency tabulation.

To measure the Q of a coil:

Set the CAL-Q switch to CAL.
Connect the coil to the L terminals.
Set the generator section to the desired frequency, and adjust the level to X1.
Set the CAL-Q switch to Q.
Adjust the resonating condenser accurately for maximum indication on the meter.
Read the Q value on the meter.
(If the meter reads off scale, switch to CAL. and adjust level to X2. Switch to Q and double the indicated value.)

To measure the distributed capacity of a coil:

Set the CAL-Q switch to CAL.
Connect the coil to the L terminals.
Set the resonating condenser to a convenient small value such as 100 MMF (C_E scale). Note this value as C_A.
Set the CAL-Q switch to Q and adjust the generator section to give a maximum indication.
Note the generator frequency.
Set the generator to a new frequency equal to half the old frequency.
Switch to CAL and check the level.
Switch back to Q and adjust the resonating condenser to give a maximum indication.
Note the value on the C_E scale and call this value C_B.
The distributed capacity is readily calculated from

$$C_D = \frac{C_B - 4C_A}{3}$$

Note: While this method is not completely accurate, it will suffice in most cases. The accuracy may be increased by repeating the measurement with different values of C_A and averaging the results.

To measure a capacity of 425 MMF or less:

Set the CAL-Q switch to CAL.
Connect a test coil to the L terminals.
Connect the unknown condenser to the C terminals.
Set the resonating condenser to a small value (50 MMF for instance). Note this value as C_A.
Switch to Q and adjust the generator section for maximum indication.
Switch to CAL and remove the unknown condenser.
Switch to Q and adjust the resonating condenser for maximum indication.
Note the reading on the C_T scale as C_B.
The unknown capacity is readily calculated from

$$C_X = C_B - C_A.$$

Note: For very small capacities, the vernier dial may be used instead of the main dial.

To measure a capacity larger than 425 MMF: *

Set CAL-Q switch to CAL.
Connect a test coil of known inductance to the L terminals.
Connect the unknown condenser to the C terminals.
Switch to Q and adjust the generator for maximum reading.
Note the capacity on the C_T scale as C_A.
Note the generator frequency as f.
Using the inductance of the test coil as L, calculate the resonating capacity C_B from

$$C_B = \frac{1}{6.28^2 f^2 L} \qquad \text{i.e. } \omega L = \frac{1}{\omega C_B}$$

This value C_B is made up of three parts: C_A in parallel with the unknown capacity C_X and and the two in series with the 5000 MMF injection padder. The unknown is calculated from

$$C_X = \frac{5000\ C_B}{5000 - C_B} - C_A$$

SERVICE

In event continued operational difficulties of the completed instrument are experienced, may we remind you that the facilities of the Heath Company Service Department are at your disposal. Your instrument may be returned for inspection and repair for a service charge of $5.00 plus the cost of any additional material that may be required. THIS SERVICE POLICY APPLIES ONLY TO COMPLETED INSTRUMENTS CONSTRUCTED IN ACCORDANCE WITH THE INSTRUCTIONS AS STATED IN THE MANUAL. Instruments that are not completed or instruments that are modified will not be accepted for repair. Instruments showing evidence of acid core solder or paste fluxes will be returned NOT repaired.

The Heath Company is willing to offer its utmost cooperation to assist you in obtaining the proper operation of your instrument and therefore the factory repair service is available for a period of one year from the date of purchase.

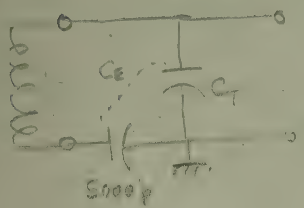
NOTE: Before returning this unit, be sure that all parts are securely mounted. Attach a tag to the instrument, giving name, address and trouble experienced. Pack in a rugged container, preferably wood, using at least three inches of shredded newspaper or excelsior on all sides. Do not ship in the original kit carton as this carton is not considered adequate for safe shipment of the completed instrument. Ship by prepaid express, if possible. Return shipment will be made by express collect. Note that a carrier cannot be held liable for damages in transit if PACKING IN HIS OPINION is insufficient.

Prices are subject to change without notice. The Heath Company reserves the right to change the design of this instrument without incurring liability for equipment previously supplied.

WARRANTY

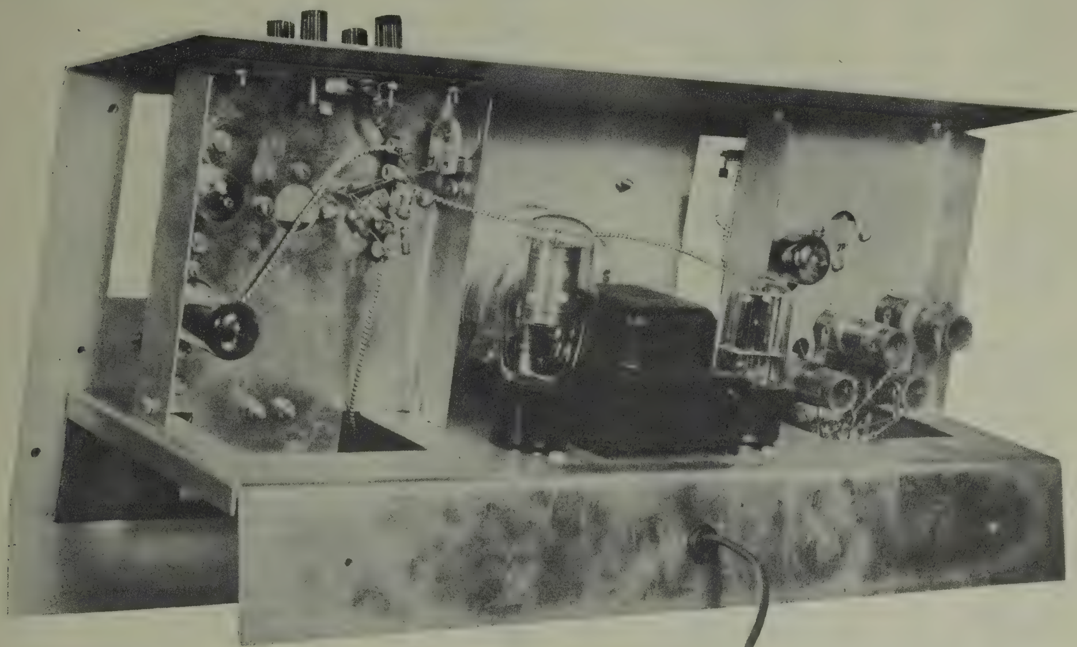
The Heath Company limits its warranty of any parts supplied with any Heathkit (except tubes, meters and rectifiers, where the original manufacturer's guarantee only applies) to the replacement within three (3) months of said part, which when returned with prior permission, postpaid, was, in the judgment of the Heath Company, defective at the time of sale.

The assembler is urged to follow the instructions exactly as provided. The Heath Company assumes no responsibility or liability for any damages or injuries sustained in the assembly of the device or in the operation of the completed instrument.



HEATH COMPANY
Benton Harbor, Michigan

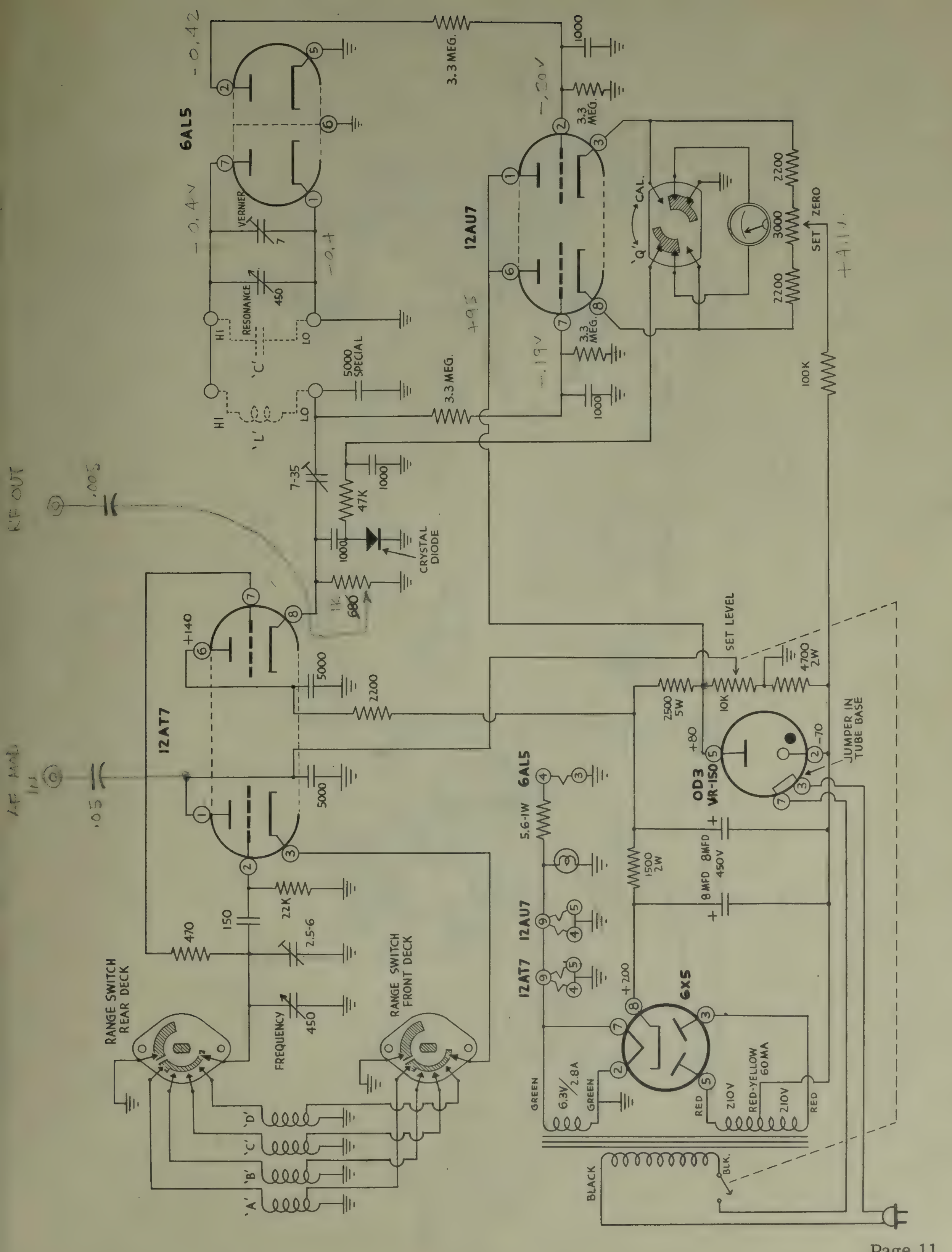
Simpler method: Set C_T at 50p, C_x connected. Tune for resonance. Disconnect C_x, connect a known capacitance C_s so that resonance can be obtained on C_T scale. Then $C_x = \Delta C_T + C_s$ This eliminates freq. calibration from the measurement.

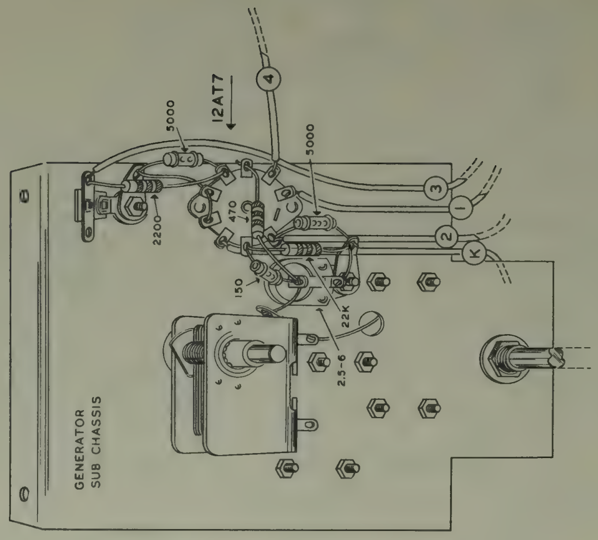


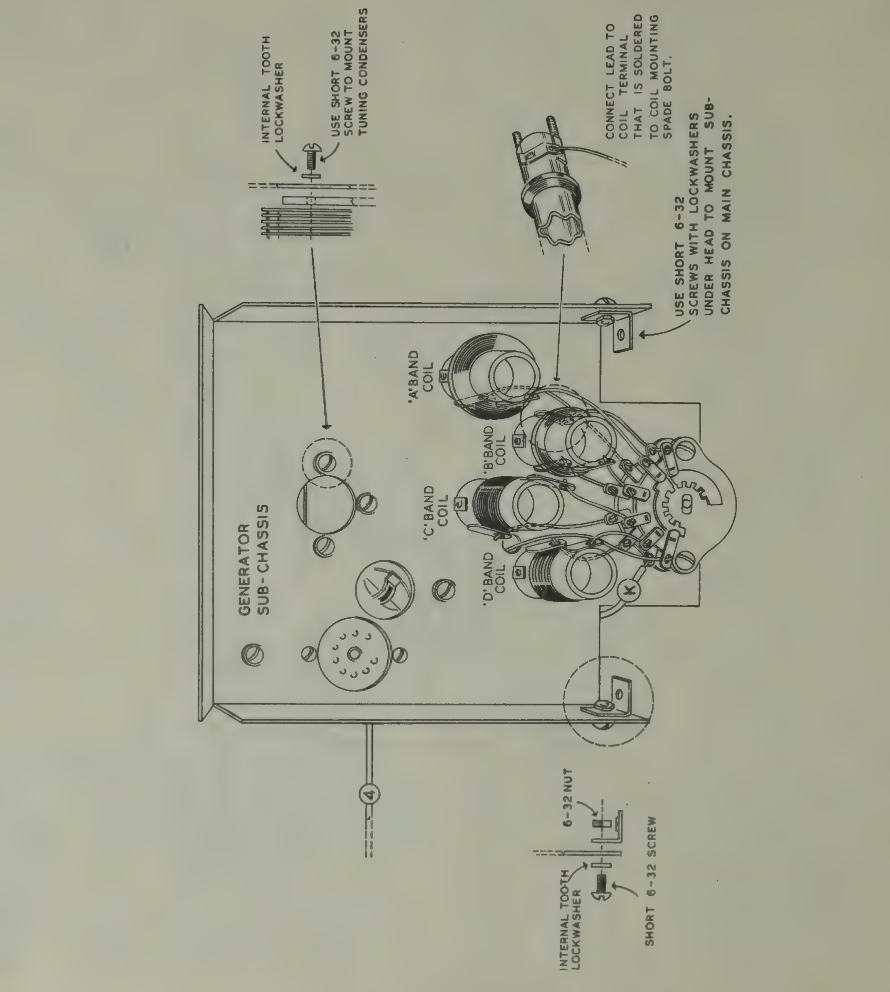
PARTS LIST

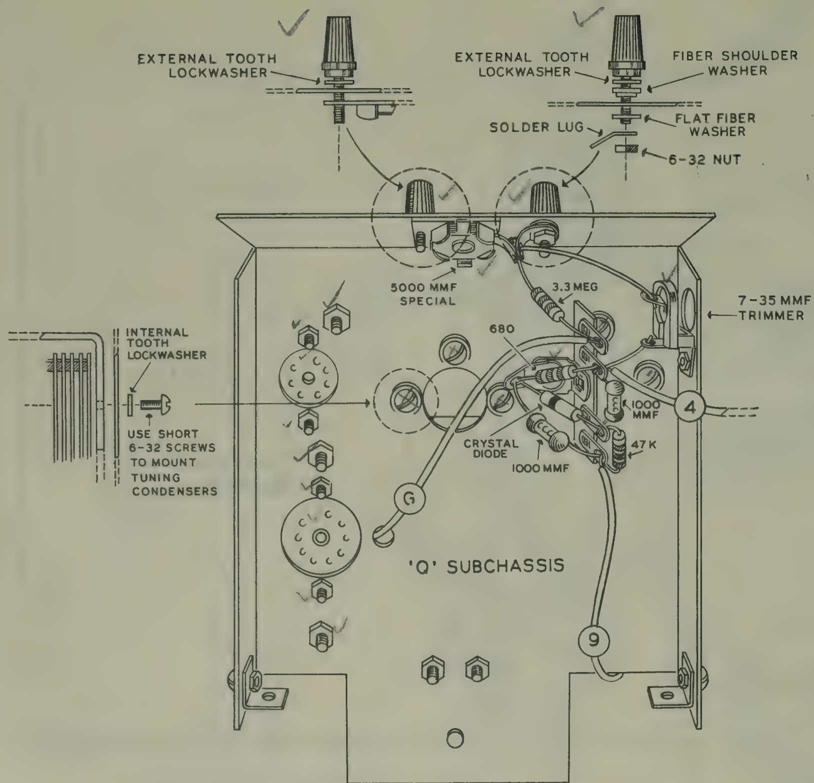
Part No.	Parts Per Kit	Description
Resistors		
1-6	1	470 Ohms
1-7	1	680 Ohms
1-44	3	2200 Ohms
1-22	1	22K Ohms
1-25	1	47K Ohms
1-26	1	100K Ohms
1-38	4	3.3 Meg. Ohms
1-41A	1	5.6 Ohm 1 watt
1-14B	1	1500 Ohm 2 watt
1-2B	1	4700 Ohm 2 watt
3-1E	1	2500 Ohm 5 watt
Controls		
11-9	1	3000 Ohms w.w.
19-2	1	10K Ohms w. switch
Condensers		
20-26	1	5000 MMF special
21-11	1	150 MMF
21-14	4	1000 MMF
21-15	2	5000 MMF
25-3	1	8 + 8 MFD 450 volt
26-11	2	450 MMF tuning
26-12	1	7 MMF tuning
31-7	1	2.5-6 MMF
31-5	1	7-35 MMF
Coils		
40-11	1	Band "A" coil
40-12	1	Band "B" coil
40-13	1	Band "C" coil
40-14	1	Band "D" coil
40-23	1	Test coil
Transformer—Crystal—Switches		
54-5	1	Power transformer
56-1	1	Crystal diode
63-48	1	4-position switch
63-49	1	DPDT—NS switch
Wire		
89-1	1	Line cord
212-M2	1	Brass strip
340-2	1	Length bare wire
344-1	1	Length hookup wire
346-1	1	Length sleeving
349-1	1	Length dial cord
Knobs—Pilot light parts		
462-4	1	Acorn knob
462-6	2	Tuning knobs
462-M11	4	Pointer knobs
100-M10	2	Dial pointers
252-12	1	Pilot light nut
413-1	1	Pilot light jewel
434-22	1	Pilot light socket
455-1	1	Pilot light bushing

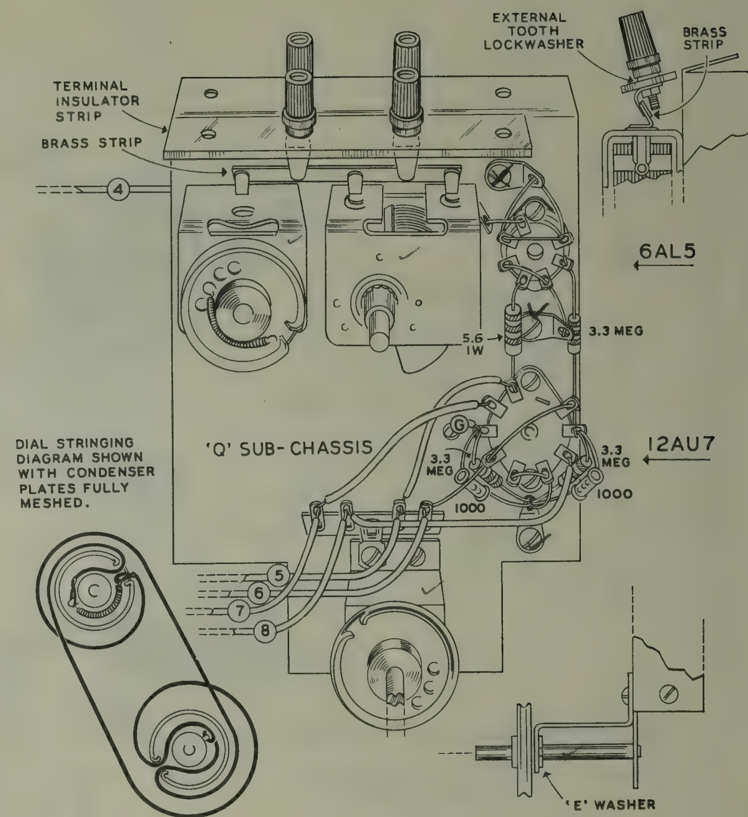
Part No.	Parts Per Kit	Description
Sockets—Terminals		
434-2	2	Octal sockets
434-16	2	Noval 9-pin sockets
434-34	1	Miniature 7-pin socket
427-2	4	Terminal bases
100-M16	4	Terminal caps
75-9	1	Terminal insulator strip
431-1	1	1-lug terminal strip
431-3	1	3-lug terminal strip
431-5	2	4-lug terminal strips
Meter—Tubes—Lamp		
407-17	1	50 microamp. meter
411-17	1	6X5 tube
411-24	1	12AT7 tube
411-25	1	12AU7 tube
411-32	1	OD3/VR150 tube
411-40	1	6AL5 tube
412-1	1	#47 lamp
Metal Parts		
90-18	1	Cabinet
100-M19	2	Dial drive pulleys
200-M40	1	Chassis
200-M41	1	Gen. subchassis
200-M42	1	"Q" subchassis
203-M41F31	1	Panel
204-M42	1	Drive Shaft bracket
205-M17F33	1	Gen. dial plate
205-M17F34	1	"Q" dial plate
205-M18	1	Assembly template
453-M6	1	Drive shaft
Hardware		
250-2	6	3-48 screws
250-7	17	6-32 x 3/16 screws
250-8	17	#6 x 3/8 Sheet metal screws
250-9	18	6-32 x 3/8 screws
250-15	2	8-32 x 1/8 pointer set screws
250-16	2	8-32 x 3/16 pulley set screws
250-22	4	8-32 knob set screws
252-1	6	3-48 nuts
252-3	33	6-32 nuts
252-4	2	8-32 nuts
252-7	4	Control nuts
253-1	1	#6 flat fiber washer
253-2	1	#6 Fiber shoulder washer
253-10	3	Control nickel washers
253-11	1	"E" washer
254-1	37	#6 lockwashers (int.)
254-2	2	#8 lockwashers
254-5	4	Control lockwashers
254-6	4	#6 lockwashers (ext.)
254-7	6	#3 lockwashers
259-1	9	#6 solder lugs
73-1	2	3/8 rubber grommets
204-9	4	Angle brackets
258-1	1	Dial cord spring
261-1	4	Rubber feet

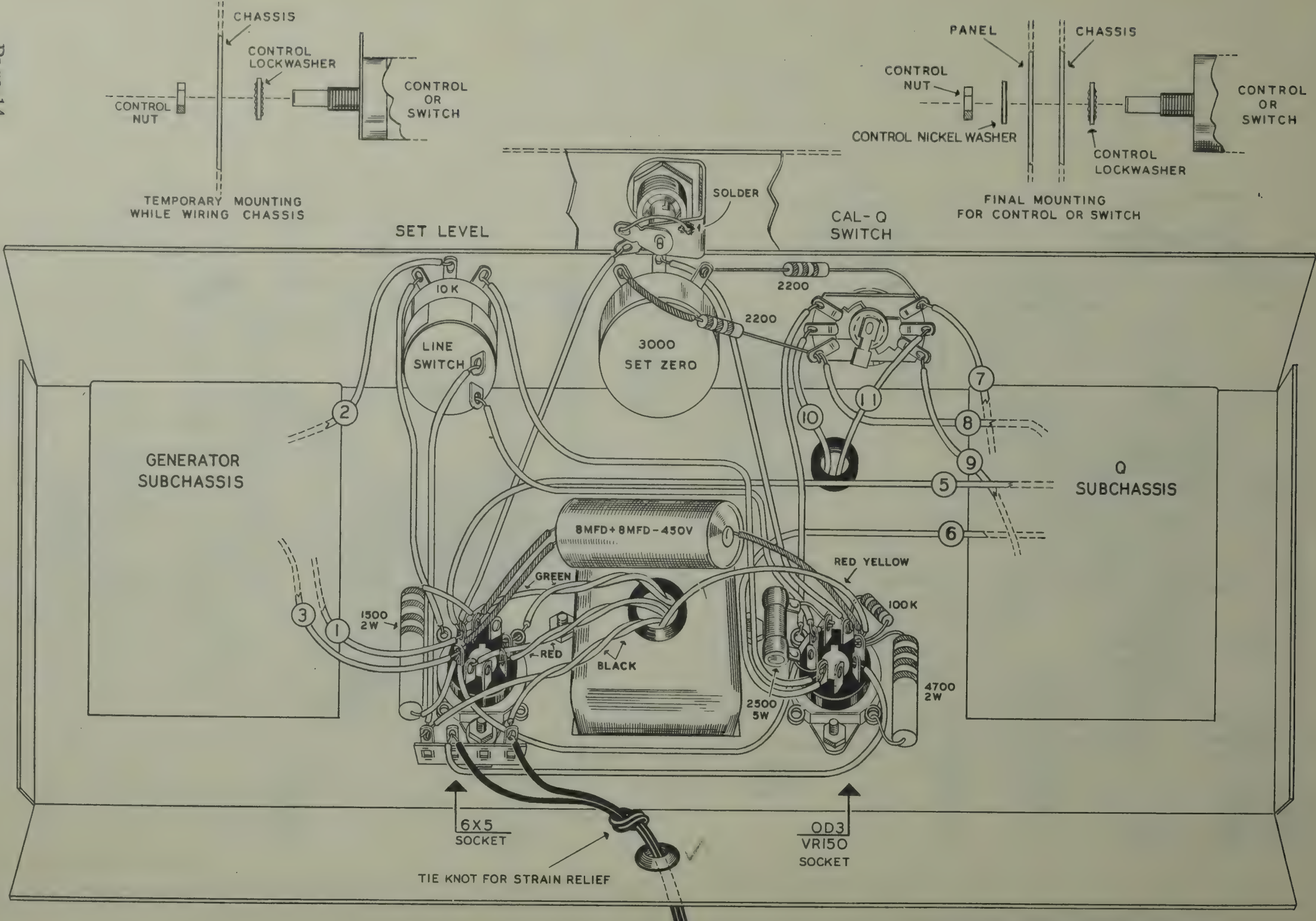

6AL5
12AU7
12AT7
OD3
VR-150
6X5
3.3 MEG.
1000
VERNIER
7
RESONANCE
450
HI
LO
'C'
'L'
5000 SPECIAL
7-35
47K
CRYSTAL DIODE
CAL.
'Q'
SET ZERO
2200
3000
100K
SET LEVEL
2500 5W
10K
4700 2W
JUMPER IN TUBE BASE
5000
2200
22K
150
470
2.5-6
FREQUENCY
RANGE SWITCH REAR DECK
RANGE SWITCH FRONT DECK
'A'
'B'
'C'
'D'
5.6-1W
1500 2W
8 MFD 450V
8MFD
GREEN
6.3V/2.8A
RED
210V
RED-YELLOW 60 MA
BLACK
BLK.
RF OUT
.005
.05


12AT7
4
5000
5000
2200
470
150
22K
2.5-6
3
1
2
K
GENERATOR SUB CHASSIS

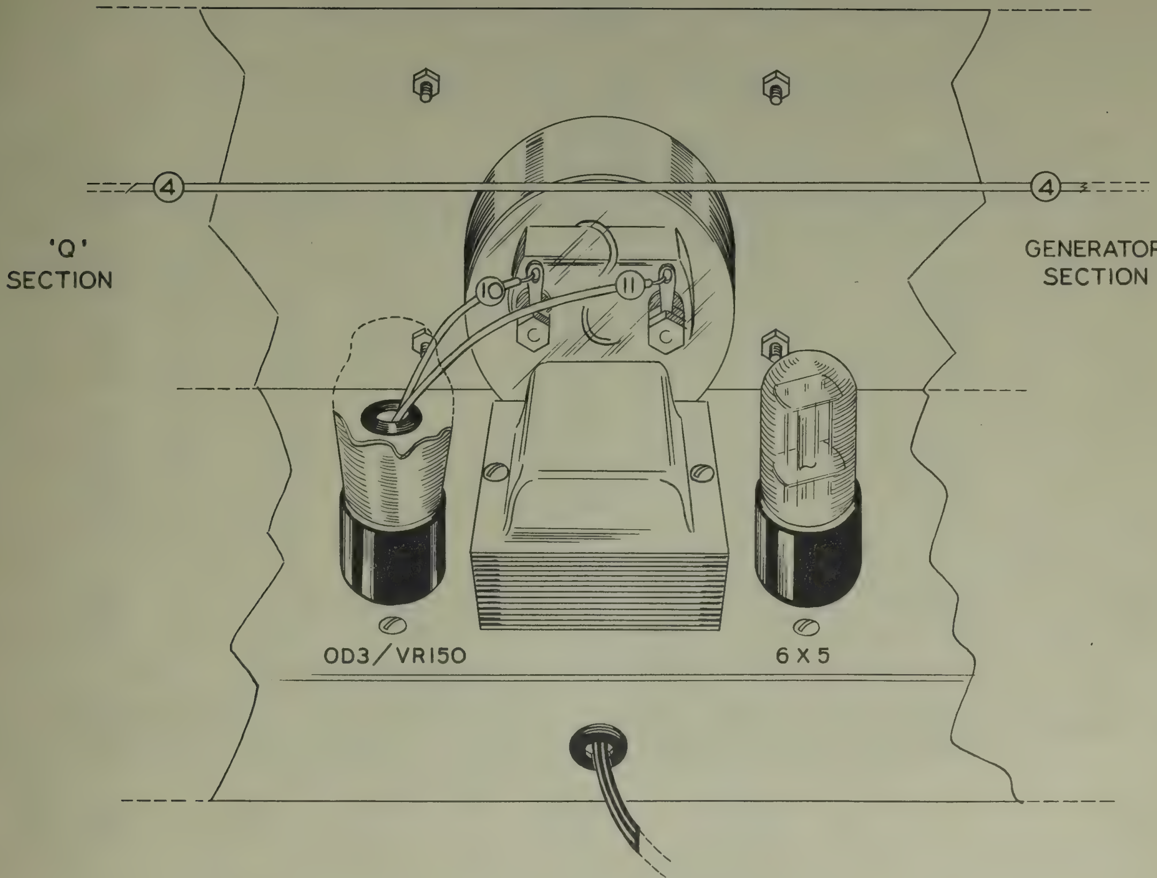

INTERNAL TOOTH LOCKWASHER
USE SHORT 6-32 SCREW TO MOUNT TUNING CONDENSERS
CONNECT LEAD TO COIL TERMINAL THAT IS SOLDERED TO COIL MOUNTING SPADE BOLT.
USE SHORT 6-32 SCREWS WITH LOCKWASHERS UNDER HEAD TO MOUNT SUB-CHASSIS ON MAIN CHASSIS.
'A' BAND COIL
'B' BAND COIL
'C' BAND COIL
'D' BAND COIL
K
GENERATOR SUB-CHASSIS
4
6-32 NUT
INTERNAL TOOTH LOCKWASHER
SHORT 6-32 SCREW


EXTERNAL TOOTH LOCKWASHER
EXTERNAL TOOTH LOCKWASHER
FIBER SHOULDER WASHER
FLAT FIBER WASHER
SOLDER LUG
6-32 NUT
5000 MMF SPECIAL
3.3 MEG
7-35 MMF TRIMMER
INTERNAL TOOTH LOCKWASHER
680
1000 MMF
4
USE SHORT 6-32 SCREWS TO MOUNT TUNING CONDENSERS
CRYSTAL DIODE
1000 MMF
47 K
G
'Q' SUBCHASSIS
9


TERMINAL INSULATOR STRIP
BRASS STRIP
EXTERNAL TOOTH LOCKWASHER
BRASS STRIP
4
6AL5
5.6 1W
3.3 MEG
'Q' SUB-CHASSIS
G
3.3 MEG
3.3 MEG
12AU7
1000
1000
DIAL STRINGING DIAGRAM SHOWN WITH CONDENSER PLATES FULLY MESHED.
5
6
7
8
'E' WASHER

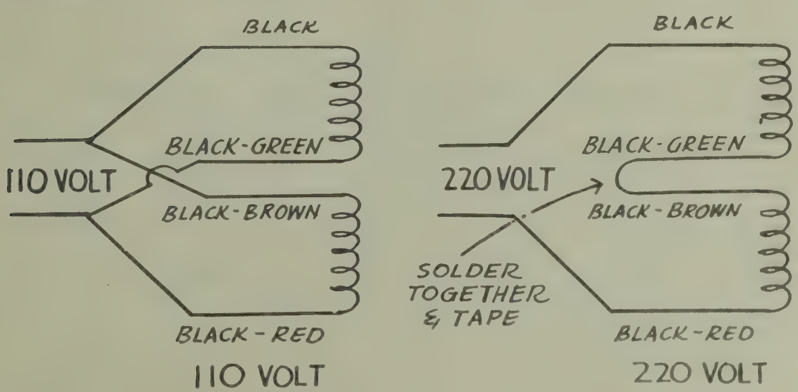


NOTE: TRANSFORMER PRIMARY LEADS MAY BE EITHER BLACK AND BLACK OR BLACK-RED AND BLACK.



WIRING OF EXPORT TYPE
110/220 VOLT POWER
TRANSFORMERS

These transformers have a dual primary for use on either 110 Volts or 220 Volts. Wire as shown.



Notes

RECEIVED in
FEB 13 1973
ENGINEERING DEPT.

APPROX. INCANDESCENT AND NIGRESCENT DATA FOR SOME VACUUM TUNGSTEN FILAMENT MINIATURE LAMPS

(Times in Milliseconds-
Photocell response curve similar to human eye)

Lamp No.	Design Volts	Design Amps	Life-Hrs	At Design Volts Incandescent Time to 90% Max.	At Design Volts Nigrescent Time to 10% Max.	At 50% Design Volts Incandescent Time to 90% Max.	At 50% Design Volts Nigrescent Time to 10% Max.
1810	6.3	.40	3,000	150	50	325	90
44	6.3	.25	3,000	120	40	250	60
47	6.3	.15	3,000	85	20	190	40
755	6.3	.15	50,000	120	35	250	55
330	14	.08	750	55	19	130	40
756	14	.08	50,000	100	27	225	50
757	28	.08	50,000	90	30	200	40
685	5.0	.06	100,000+	90	25	---	--
1819	28	.04	1,000 (nom)	70	20	150	27
387	28	.04	25,000	70	18	160	30
1843	28	.022	3,000	50	16	110	25
2158	3.0	.015	10,000+	70	18	---	--
1869	10	.014	50,000+	85	22	---	--
#12	6.3	0.15A	10,000+	100	33		

Results with resistance in circuit - 25.2 volts with series resistor to reduce voltage to lamp to 6.3 volts:

44	290	40
47	220	20

Some factors affecting incandescent and nigrescent times.

1. Gas filled lamps are faster than vacuum lamps (other factors being equal).
2. Resistance in the circuit increases the incandescent time only.
3. The lower the current, the faster the lamp (other factors being equal).
4. Longer life lamps are slower.
5. At reduced voltages, lamps are slower.
6. With cell response more sensitive in the red or infrared region--the incandescent times decrease and nigrescent times increase.

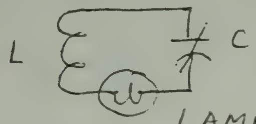
	Inc	Nig
@ 5.5V	150	40
@ 6.3V	75	22

185

J. D. Lash
Product Planning-381
2/65

WAVEMETERS

SIMPLEST (CURRENT) $f = 1/2\pi\sqrt{LC}$

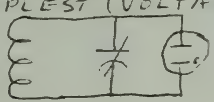


$$L(\mu H) \times C(pF) = \frac{25{,}330}{f^2(MHz)}$$

LAMP #47 6.3V @ .15A = .95 W
#49 2V @ .06A = .12 W

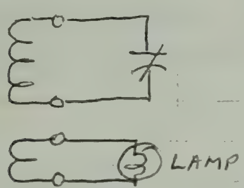
NOTE: SHARPEST WITH A SHORT CIRCUIT INSTEAD OF LAMP.
MILLEN USES THIS DESIGN, SEE ALSO TURNER, DEC. 47 CQ

SIMPLEST (VOLTAGE)



NE-2 NEON LAMP (FIRES AT 70-90 V)

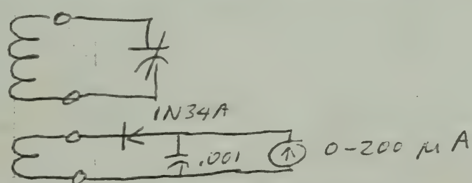
LAMP INDUCTIVELY COUPLED (McMURDO SILVER, 1947) (MODEL 903)



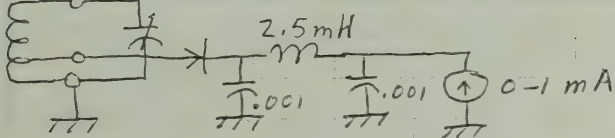
McMURDO-SILVER COILS

#100	1.6-3.7 MHz	#104	40-100 MHz
#101	3.5-8 MHz	#105	100-300 MHz
#102	8-19 MHz	#106	400-500 MHz
#103	17-40 MHz		

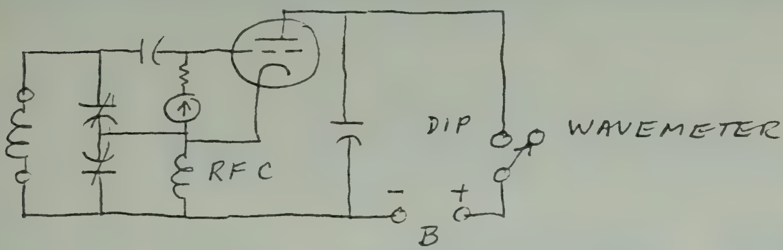
DETECTOR INDUCTIVELY COUPLED (MODIFIED 903) RAND, MAY 48 QST



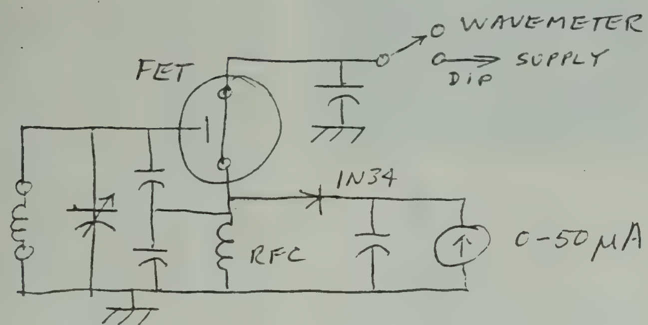
DETECTOR TAP COUPLED, LEW McCOY, MARCH 67 QST



DIPPERS AS WAVEMETERS

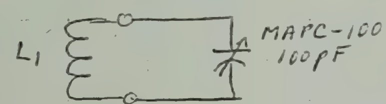


GRID – DIP



FET DIPPER

HOME PROJECT (1): FIND 10, 18, AND 24 MHz



L_1

7-14 MHz 14.5 T, 1" DIA, .45" LONG, 32 TPI

14-28 MHz 7 T, 1" DIA, .43" LONG, 16 TPI

RESONANCE	7	10	14	18	21	24	28
PICOFARADS	90	44.1	22.5				
			90	54.7	40.2	30.8	22.5

HOME PROJECT (2): FIND 160 METERS

L = 52.3 μH = 45 T, 1 ½" DIA, 1 ½" LONG

1.8 MHz 149 pF

2.0 MHz 121 pF

3.6 MHz 37.4 pF

SPRING, 1961

NUMBER 28

The NOTEBOOK

BOONTON RADIO CORPORATION · BOONTON, NEW JERSEY

910

The BRC UHF Q Meter
A New and Versatile Tool for Industry

CHARLES W. QUINN, *Sales Engineer*

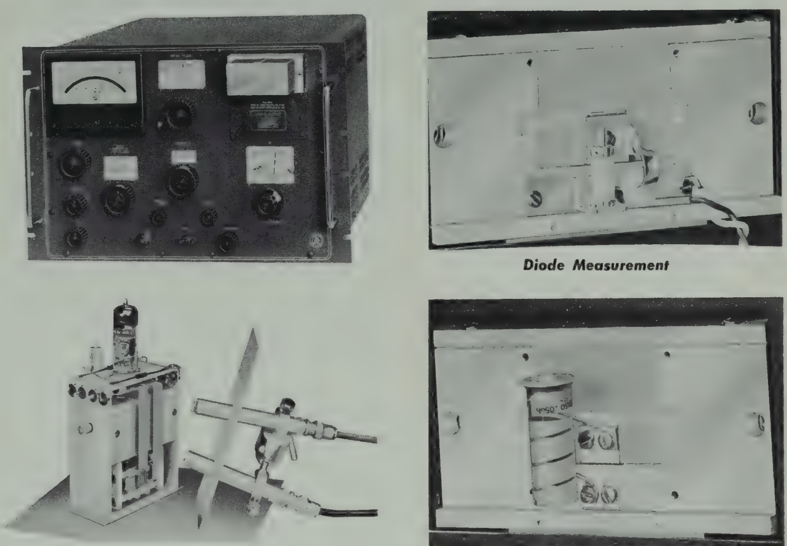
Q Meters have been serving the electronic industry for more than 25 years. Their original application was in the design of resonant circuits, in the early days of radio-frequency communication and broadcasting. Since that time, Q Meter applications have multiplied many times.[1-5] The basic theory of Q Meter operation, however, had not changed in all these years, until the development of the new Type 280-A UHF Q Meter.[6] With this change in Q meter theory, the applications will be again multiplied. It is these applications which are the subject of this article. Conventional measurements, as well as unconventional measurements, which include measurements of external resonators and components, and "in circuit" Q measurements, will be described.

PURPOSE

The prime purpose of the UHF Q Meter is to provide industry with a versatile impedance measuring device that will extend Q Meter measurements into the UHF region. The UHF Q Meter is a completely self-contained instrument capable of measuring, rapidly, conveniently, and directly; Q, capacitance, and inductance. Until the advent of the UHF Q Meter, a signal generator, a frequency measuring device, a dc amplifier, and coupling devices were required to make these tedious measurements. Inductance and capacitance, which are now measured directly on the calibrated capacitor, could not even be measured with the above-mentioned equipment.

OPERATING PRINCIPLE

To aid the reader in understanding the theory of the Type 280-A UHF Q Meter it might be well, at this point, to compare its operation with the lower frequency Q Meters, Types 260-A and 190-A. This comparison is especially necessary if use of the instrument, beyond the obvious, is to be understood.



Diode Measurement

"In-circuit" Q Measurement

Coil Measurement

Figure 1. Typical Applications of the UHF Q Meter

Preivous Q Meters utilized the definition that:

$$Q = \frac{X_{LS}}{R_S} = \frac{R_P}{X_{LP}},^*$$

*S and P subscripts indicate series and parallel configurations respectively.

as well as the fact that the voltage (V_C), measured across C (the Q capacitor), has the following relationship at resonance:

$$V_C = QV_S, \text{ or } Q = \frac{V_C}{V_S}^*$$

*Within the Q Meter Q limits (10 to 625).

V_C is the voltage injected in series with the resonant circuit (Figure 2A). If V_S is held constant, then Q is directly proportional to V_C. This basic principle, employed in all BRC Q Meters to date, is known as the "resonant rise" system of making Q measurements.

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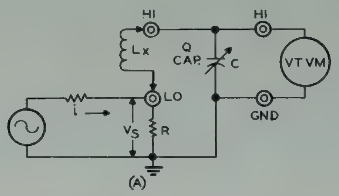
The UHF Q Meter uses the peak of the resonant rise to indicate resonance, but employs the bandwidth relationship to determine Q, where:

$$Q = \frac{f_r}{\Delta f} \qquad (1)$$

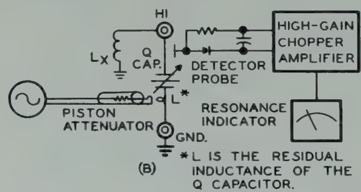
This relationship is shown in Figure 3. Δf is the frequency between the two 0.707 voltage or half-power points, and f_r is the frequency at the resonant peak. As is indicated in Figures 2B and 4, there are other more subtle differences between the UHF Q Meter and the lower frequency Q Meters. These will be discussed later in this article.

FIELDS OF APPLICATION

Because of its frequency range, the UHF Q Meter will serve many fields of the electronic industry. Some examples of these fields ar given below.



Simplified Circuit — Conventional Q Meter (Type 260-A)



Simplified Circuit — UHF Q Meter Type 280-A

Figure 2. Comparison of Q Measuring Circuit in Conventional Q Meters and the UHF Q Meter

FIELD	SPECIFIC APPLICATIONS
Missile and Rocketry	Telemetry and remote control systems.
Communications	Commercial, mobile airborne, relay networks, amateur radio, UHF television, and military mobile.
Navigational Aids	Glide slope
Radar and ECM	
Components and Materials Manufacturers	Inductors, cores, capacitors, UHF diodes, insulators, and resistors.
Other Fields	Accelerator, medical research, and basic research of new materials.

BASIC OR CONVENTIONAL MEASUREMENTS

Set-up Procedure

A condensed set-up procedure will be given at this point to aid in the understanding of the instrument. The same procedure is used for both conventional and unconventional measurements. Arbitrarily, it will be assumed that the Q and inductance of a small inductor is going to be measured.

1. The component to be measured is clamped to the Q capacitor terminals by means of the clamps provided (Figures 1 and 5), or by other suitable means.

2. The oscillator is adjusted to provide the desired operating frequency by means of the appropriate controls.

3. The Q capacitor is adjusted until output is indicated on the resonance indicating meter.

4. The Q capacitor or $\tilde{Q}$ (frequency) control is adjusted in conjunction with the Level Set control until the resonant peak is indicated at full scale on the meter.

5. The appropriate Q dial is locked and its knob is turned clockwise to the proper half-power point which is indicated by the Q mark on the meter.

6. The Q dial is unlocked and the knob is rotated in a counter-clockwise direction, through the resonant peak, to the opposite half-power point; also indicated by the Q mark on the meter.

7. Q is read directly on the appropriate Q dial, capacitance is read directly on the Q capacitor dial, and inductance is read directly on the integral calculator dial.

Inductance Measurements

Inductance measurements are a primary function of all Q Meters. The UHF Q Meter capacitance dial is provided with a spiral calculator to compute inductance from the capacitance reading and the operating frequency. The direct-reading inductance range is 2.5 to 146 millimicrohenries (Figure 6). Circuit Q is read directly from the CIRCUIT Q dial.

Capacitance Measurements

Capacitance measurements are second nature to a Q Meter, but are indirect measurements in that a reference inductor or "work. coil" must be used. The clamps provided with the instrument permit individual connection of the work coil and the unknown capacitor for parallel measurements. Standard Q Meter procedure is then employed to make the parallel capacitance measurements and all general Q Meter equations [2,7] apply. Q_1 and C_1 of the work coil are measured; then, with the unknown capacitor (C_X) connected, Q_2 and C_2 are also measured. The capacitance of the specimen is determined by the equation:

$$C_X = C_1 - C_2$$

and

$$Q_X = \frac{Q_1 Q_2}{Q_1 - Q_2} \times \frac{C_X}{C_1}$$

Dissipation factor measurements can be estimated by referring to Figure 7. For example, a 20-pf capacitor with an R_p of 0.3 meg. ohms can be detected at 210 Mc, using a work coil with a Q_1 of 300. The dissipation factor would then be computed at follows:

$$D = \frac{1}{Q} = \frac{X_C}{R_P} = \frac{40}{0.3 \times 10^6}$$
$$= 130 \times 10^{-6}$$
$$= 0.00013$$

Consider the possibilities if higher Q inductors or resonators are used. One precaution must be observed if a false value for C_2 is to be avoided. The Q dials (frequency dials) should always be returned to their original positions, indicated by the resonant peak of the work coil before C_X was connected.

Direct parallel capacitance measurements, over a range of 0.1 to 20 pf are possible on the UHF Q Meter. It is also possible that capacitance measurements can be extended by a "step-shunt" technique. This technique requires that an external capacitor or capacitors (C_A and C_B), within the capacitance range of the instrument, be calibrated at the frequency of measurement. The external capacitors are then connected in parallel

with another work coil and the Type 280-A internal capacitor is adjusted to peak. The external capacitors are removed as required when the unknown capacitor (C_X) is connected. Then:

$$C_X = C_A + C_B + (C_1 - C_2) \quad (2)$$

Series techniques may also be used. Some suggestions on this subject are taken up in the resistance measurement section which follows.

Resistance Measurements

Resistance measurements are also indirect measurements, and the procedure used is identical to that used for capacitance measurements. In this case, however, we are interested in the major parameter of resistance. Figure 8 shows approximate limits of measurable resistance for indicated Q_1 values of 300 and 500, Q_2 values of 20 and 10, and a $\triangle Q$ of 10. Approximate limits for both parallel and series measurements are given. The upper limits of parallel measurements may be extended by utilizing higher Q reference inductors and smaller $\triangle Q$ values. The lower limits of parallel measurements may be extended, slightly, by using additional external capacitance.

At ultra-high frequencies, series measurements present a more difficult problem. First, shunt capacitance and series inductance of the series jig must be small relative to the resistance to be measured. Secondly, a low inductance and low resistance short-circuiting device must be employed.

In the Type 280-A, circuit component contact resistance is basically the lower limiting factor in series measurements. This contact resistance usually becomes a function of the component shape and may require a special machined fixture for a given component.

A short cut to solving the multiple computations of the real component of parallel impedance measurements is illustrated in Figure 7. Curves for a given work coil, with Q_1 and frequency held constant, are plotted as a function of Q_2 and R_P. If the work coil is stable, well designed, rigid, well plated, etc., these curves, or a group of curves, can be used for general measurements over long periods of time.

SPECIAL OR NONCONVENTIONAL MEASUREMENTS

The basic parameters of L, C, and Q are often affected when brought near, or in contact with, a component to be tested. Let us consider some specific instances and determine what measurements may be made.

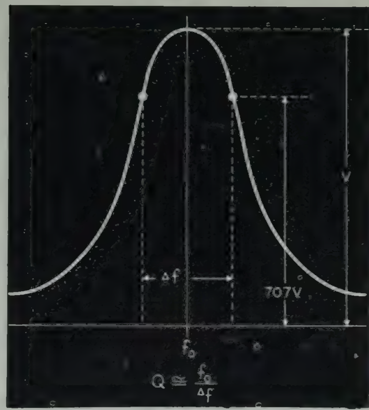


Figure 3. Q Resonance Curve

Measurements Involving Change in Inductance and Resistance

Iron cores, shells, toroids, and rods may now be tested simply, at higher frequencies, with the UHF Q Meter. It has been found that some defects are detectable in the resistive or Q_2 indication at these frequencies (210 to 610 Mc) that do not show up at the lower operating frequencies.

The ferro-resonant frequency of some ferro-magnetic components may be detected on the resonance indicating meter, if this resonance falls within the instrument frequency range.

Figure 9 suggests a possible jig design for coupling these and other components, liquids, and materials into the inductive field of a test coil. The plastic plug can be machined to precisely position the specimen so that the change in C, L, or Q falls within the range of the instrument. A change of inductance indicates a change in effective permeability and a change in Q indicates a change of specimen resistivity. A high degree of precision can be achieved in these measurements, since both the work coil and plug can be fabricated on precision machines.

A work coil and two plastic plugs, patterned after those shown in Figure 9, were made and attached to the Q capacitor terminals on the UHF Q Meter, and a few experiments were performed which produced some interesting results. In the first experiment, a group of small shell cores were inserted in the plastic plug and tested at 400 Mc. Q_1 was determined to be within 5% of 630, and Q^2 was within 5% of 284 for all cores. Inductance increased by 5%, indicating permeability greater than unity, even at 400 Mc. Core #4 showed a 5% decrease in inductance, with a drop to 135 in Q_2. This core was obviously of low-frequency material acting like a poor short circuit. This experiment indicates a technique for evaluating inductive tuning or adjustment devices and their effects upon circuit Q at ultra-high frequencies.

The author has long been curious about the effects of liquids on circuit Q. This curiosity led to the second experiment, performed to determine the effect of tap water on circuit Q, with and without a few salt crystals added. Q_2 measured for the clear water was 610. Low losses, very little change in inductance, and approximately 1% increase in distributed capacitance were noted. A pinch of salt (NaCl) was then added and the effects noted. Q_2 dropped to 255, with no inductance change apparent. It can be concluded

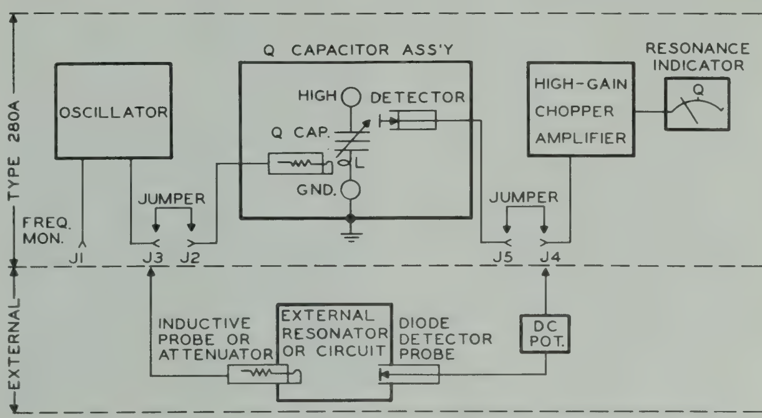


Figure 4. Block Diagram of UHF Q Meter Showing External Resonator Connections

then, that the RF resistivity or losses only change in a positive direction with the addition of salt.

These experiments point up the application of the UHF Q Meter in the UHF inductive heating field (cooking of foods, curing of adhesives and resins, etc.) where it is important to know the frequency of optimum energy absorption.

Jigs similar in theory to the one discussed above, but more sophisticated, may be constructed to detect, test, and measure more complex components and materials and to solve more exacting problems. For example, a capacitance-loaded or "end-tuned" coaxial resonator could be adapted to check toroidal behavior under truly inductive conditions and with the flux lines in a specific plane.

Measurements Involving Change in Capacitance and Resistance

The measurement of the dielectric loss factor of Teflon, Polyethlene, etc., is one of the most difficult measurements to make with any degree of accuracy. For example, high-grade Teflon is known to have a loss factor of approximately 0.00014.

The Type 280-A UHF Q Meter, with its frequency range of 210 to 610 Mc and Q range of 10 to 25,000, makes this equivalent high shunt resistance more readable. Further, since the Type 280-A employs a bandwidth measuring system; i.e., Δf is measured between the half-power points, permitting the use of frequency counting techniques; calibration and readability of the Q dials can be eliminated as a source of error and ΔQ becomes more readable, limited only by our ability to measure Δf. Let us consider the order of Δf or frequency changes that will be encountered for such a measurement.

Conditions:

1. The specimen capacitance (C_x) should be about 10pf.
2. If a plate area of 0.6 inches is used, material thickness should be 1/32 inch for approximately 10 pf C_x.
3. C_1, under these conditions, should be approximately 15pf.
4. Q_1 should be at least 500.
5. Operating frequency is 300Mc.

Solving for ΔQ: We can now solve for the expected ΔQ for a 0.0001 dissipation factor. In this case:

$$D = \frac{1}{Q_x},\ Q_x = 10{,}000.$$

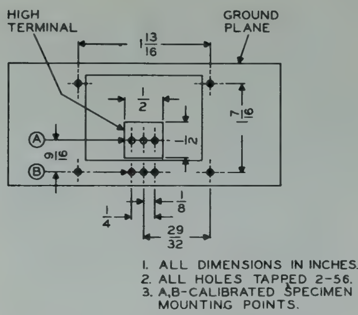


Figure 5. Q Capacitor Terminal Dimensions

Using the standard equation for Q:

$$Q_x = \frac{Q_1 Q_2}{\Delta Q} \times \frac{C_x}{C_1}. \qquad (3)$$

Let $C_x/C_1 = K = 0.66$ which is a practical ratio adjustable by manipulation of inducance or frequency and specimen thickness. Then:

$$Q_x = K \frac{Q_1 Q_2}{\Delta Q} \qquad (4)$$

since

$$Q_2 = Q_1 - \Delta Q; \qquad (5)$$

and

$$\Delta Q = \frac{K Q_1{}^2}{Q_x + K Q_1}. \qquad (6)$$

Example (for above conditions):

$$\Delta Q = \frac{.66\ (500)^2}{10{,}000 + .66 \times 500}$$

$$= \frac{.66\ (25 \times 10^4)}{10{,}330}$$

$$= 16$$

Calibrated dial divisions at this Q value are 10 units. This means that estimates from the dial reading can be within approximately 20% of this ΔQ value. With a ΔQ of 16 at a frequency (f_r) of 300 Mc, what is the frequency bandwidth change? Let us refer to this change as Δf_3. The derivation of the equation used is as follows:

$$Q_1 = \frac{f_r}{\Delta f_1},\ \Delta f_1 = \frac{f_r}{Q_1} \qquad (7)$$

$$Q_2 = \frac{f_r}{\Delta f_2},\ \Delta f_2 = \frac{f_r}{Q_2} \qquad (8)$$

$$\Delta Q = Q_1 - Q_2,\ Q_1 > Q_2$$

$$\Delta f_3 = \Delta f_2 - \Delta f_1 \qquad (9)$$

$$= \frac{f_r}{Q_2} - \frac{f_r}{Q_1}$$

Clearing:

$$\Delta f_3 = \frac{Q_1 f_r - Q_2 f_r}{Q_1 Q_2}$$

$$= \frac{f_r\ (Q_1 - Q_2)}{Q_1 Q_2}$$

$$= \frac{f_r\ (\Delta Q)}{Q_1 Q_2} \qquad (10)$$

To compute the above example:

$$\Delta f_3 = \frac{300 \text{ Mc} \times 16}{500 \times 484}$$

$$= .0198 \text{ Mc or } 19.838 \text{ kc}$$

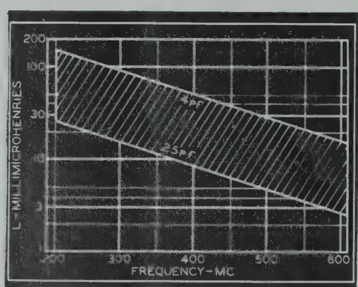


Figure 6. Inductance Range of the UHF Q Meter (Direct Reading)

From the above example, two factors stand out as important to the accuracy of measurement: First, the value of the ratio K in equation 4, especially if the Q dial readout is to be used, should approach as close to unity as possible to optimize readability. Secondly, equations 7, 8, 9, and 10 indicate that a frequency measurement technique can be used to measure Q_1, Q_2, and ΔQ.

Use of an Auxiliary Frequency Counter to Measure Loss Factor

Fortunately for those with dielectric loss measurement problems, the art of frequency measurement is highly refined and is really a simple solution to the loss-factor measurement problem. A popular frequency measuring device found in most laboratories is the frequency counter. This instrument, with a suitable transfer oscillator, has more than sufficient accuracy and resolution for this application. The frequency counter is connected to jack J1 at the

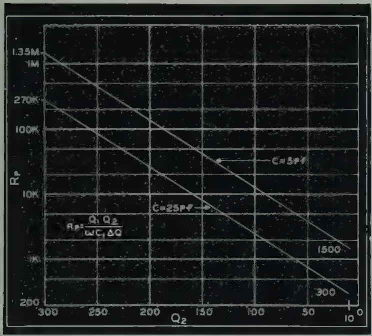


Figure 7. R_p versus Q_2 and C_x

rear of the Type 280A (Figure 4) which is provided especially for monitoring the UHF Q Meter frequency. With this technique the accuracy of measurement is determined by the short-term frequency stability of the Type 280-A and the stability of the half-power indicator in its most insensitive position (position of maximum stability). In this mode of operation, 0.5 kc per minute per 100 megacycles can be resolved with good repeatability. For this method of dielectric measurements, it is convenient to derive the equations for Q_x and D_x (dissipation factor) in terms of frequency. Considering the relationships of equations 7 and 8, equation 3 can be written:

$$Q_x = \left[\frac{\dfrac{f_r}{\triangle f_1} \times \dfrac{f_r}{\triangle f_2}}{\dfrac{f_r}{\triangle f_1} \times \dfrac{f_r}{\triangle f_2}}\right] \times \frac{C_x}{C_1}$$

$$O_x = \frac{f_r^2}{\triangle f_1 \times \triangle f_2} \times \frac{\triangle f_1 \times f_2}{\triangle f_2 \times f_r - \triangle f_1 \times f_r} \times \frac{C_x}{C_1}$$

$$= \frac{f_r^2}{f_r\,(\triangle f_2 - \triangle f_1)} \times \frac{C_x}{C_1}$$

$$= \frac{f_r}{(\triangle f_2 - \triangle f_1)} \times \frac{C_x}{C_1} \qquad (11)$$

$$D_x = \frac{\triangle f_2 - \triangle f_1}{f_r} \times \frac{C_1}{C_x} \qquad (12)$$

Dielectric loss factor measurements in this range, were heretofore obtained by refined techniques and extreme skill. The Type 280-A $\triangle f$ technique can achieve $\pm 10\%$ accuracy (or one part in the fifth place) with considerable simplification of the measurement procedure in this frequency range.

Measurement of Semiconductor Components and Materials

Since one of the key features of the new UHF Q Meter is high detector gain, low RF levels are available across the component to be tested. The level can be selected by the front panel SENSITIVITY control from 25 to 250 millivolts. Of the many components measurable in this RF voltage range, the variable-capacitor diode is one of the best examples. Here, one is most concerned with the behavior of Q and capacitance as a function of bias and frequency. With 0.025 volts RF across the diode, investigations to almost zero bias (0.1v dc) can be made. RF impedance of detector and mixer diodes can be determined using standard Q Meter equations[7]. A suggested design for a diode jig, with provisions for biasing, is shown in Figure 1. Other parametric and nonlinear components, including h_{ie}, h_{oe}, and h_{ob} of some UHF transistors, may be measured in a similar manner. Semiconductor material resistivity can be measured in the electrostatic manner previously described under "Measurements Involving Change in Capacitance and Resistance", or relative resistivity can be obtained using the inductive jig previously described under "Measurements Involving Change in Inductance and Resistance."

External Resonator and "In Circuit" Measurements

One of the most interesting phases of the new UHF Q Meter application is the measurement of external resonators and "in circuit" measurements. Referring to Figure 2B and 4, observe that there is really no direct connection to

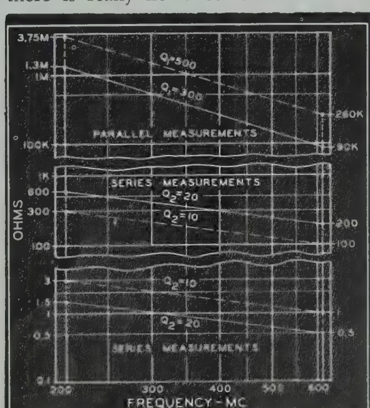


Figure 8. Approximate Resistance Range of the UHF Q Meter

the injection and detection circuits. The RF signal is actually magnetically coupled or induced into the Q capacitor by a piston-type inductive attenuator. This device is a tubular probe, with a single turn of wire at its end. The detector circuit is similar to a conventional diode probe used on many RF vacuum tube voltmeters and is coupled to the Q capacitor by merely bringing one end of it near the electrostatic field of the stator structure.

The fact that there is actually no conductive connection to the circuit under test suggests many possible configurations for making measurements. As shown in Figure 4, connections to the Q capacitor assembly have been made through a series of jacks and jumpers located at the rear of the instrument. This means that the oscillator and high-gain amplifiers may be disconnected from the Q capacitor.

External Resonators

First, let us assure that we have a coaxial resonator and need to know its Q and resonant frequency. Due to the physical size of the component, it can not be mounted on the Q capacitor terminals. Even if it could be mounted, the minimum capacitance of 4pf would prohibit uncorrected measurements. The Type 280-A, with appropriate accessories, can make these measurements on the bench rather than on the instrument. Figure 4 shows the connections for a typical resonator circuit. The piston attenuator and diode probes shown in Figures 1 and 4 will be made available as optional accessories for the Type 280-A.

The procedure for making this measurement is basically the same as for making conventional measurements, except that the "Level Set" controls (Q capacitor piston attenuator and Q capacitor controls) are no longer operative. The motion of the attenuator probe and adjustment of the dc potentiometer serve as the "Level Set" control once the detector probe has been positioned. The frequency or CIRCUIT Q dials are then tuned to obtain the resonant peak. The resonant frequency is read directly on the frequency dial, or by means of external frequency measuring equipment if desired. The Q measuring procedure is the same as described above for inductors.

Care must be taken to avoid unexpected loading of the resonator. Prevention of this loading is one function of the coupling block and is also the

reason that an adjustment is provided on the attenuator probe. Two Q readings, at different detector probe and attenuator probe settings, will establish the extent of loading. If there is any loading, Q_2 will be different than Q_1.

A plot of two or three Q readings as a function of coupling will show that Q approaches a limit, asymptotic to the Q value, at which the Type 280-A injection and detection circuit reflected losses are negligible. This Q value is the actual unloaded Q of the resonator under test.

In resonators of this type, Q is important as a method of determining bandwidth in receivers. The effects of circuit loading can be determined and optimized.

As a power handling device, Q is related to efficiency (E) as follows:

$$E = 100\left(1 - \frac{Q_L}{Q_{UL}}\right)\ \%, \quad (13)$$

where Q_L = Q loaded and Q_{UL} = Q unloaded.

"In Circuit" Measurements

A distinct advantage of the UHF Q Meter is its ability to measure the Q of resonant circuits (resonators) as they are connected and mounted in actual use; i.e., "in-circuit" measurements. This is extremely important, since the behavior of most resonators is a function of many things. Resonators may take many forms; i.e., coaxial, cavity, open lines, strip lines, butterfly tanks, etc. An example of a typical "in-circuit" measurement problem is shown in Figure 1. Here, flat strips are used to form a resonator for a developmental RF amplifier. It is important to know the Q_L and Q_{UL} of the resonator to determine the optimum efficiency versus bandwidth compromise. Coupling was achieved as illustrated, and the following example readings were made at 400 Mc: $Q_{UL} = 400$, $Q_L = 40$, E = 100 (1 - 40/400) = 90%. It was found that due to radiation losses, Q_{UL} dropped to 300 with the shield removed, resulting in an efficiency of 100 (1 - 40/300) % = 84%. These efficiencies were adequate, but a different tube type and aluminum shields resulted in a Q_{UL} of 100. Efficiency was 60% under these conditions and, therefore, this may prove to be an unusuable configuration.

An extension of this type of measurement can be applied to mating components, or may be used to determine

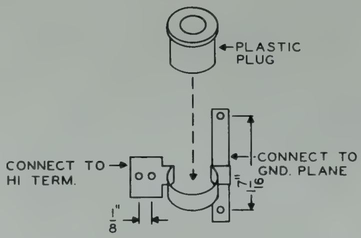


Figure 9. Suggested Design for an Inductance Jig

Q at the self-resonant frequency of an inductor. The components are placed on a small ground plane in the vicinity of the probes, or in a convenient shield, to limit radiation losses and body capacitance effects. By this means, any tuning or fixed capacitor desired may be employed.

It is important to realize that measurements made in the manner described in this section yield Q_e; i.e., the effective Q of the component and associated circuit inperceptably influenced by the Q Meter, if care is used to determine sufficient probe decoupling. This is the actual "in-circuit" Q and can be used directly in circuit computations. The Type 280-A UHF Q Meter is the only Q Meter in existance that can measure, directly, the Q of a circuit that is resonant at the frequency of measurement.

To measure circuit "stray" capacitance, a coil may be calibrated on the Q capacitor and then soldered into the circuit at the desired points. The circuit capacitance can then be computed from the relationship for resonance:

$$f = \frac{1}{\omega\sqrt{LC}}$$

or

$$C = \frac{1}{f^2\,\omega^2 L} \quad (14)$$

The same technique can be applied to circuit inductances.

CONCLUSION

We have attempted to describe some of the applications of the new UHF Q Meter Type 280-A, but realize that there will be many more jobs for this versatile instrument; some of which are not apparent at this writing. These will provide worthwhile subject matter for future articles in The Notebook.

REFERENCES

1. "Q Meter Comparison," BRC Notebook No. 2, Summer, 1954.
2. "A Versatile Instrument — The Q Meter," Cook, L.O., BRC Notebook No. 4, Winter, 1955.
3. "Measurement of Dielectric Materials and Hi Q Capacitors with the Q Meter, Riemenschneider, N.L., BRC Notebook No. 8, Winter, 1956.
4. "Q Meter Techniques," Riemenschneider, N.L., BRC Notebook No. 13, Spring, 1957.
5. "Applications of the Q Comparator," Quinn, C.W., BRC Notebook No. 25, Spring, 1960.
6. "Design of a UHF Q Meter," Gorss, C.G., BRC Notebook No. 27, Winter, 1961.
7. "The Nature of Q," Moore, W.C., BRC Notebook #1, Spring, 1954.

SERVICE NOTE

RX Meter Null Indicator

Proper operation of the Type 250-A RX Meter is dependent upon the correct balancing of the bridge circuit, and the bridge circuit cannot be correctly balanced if the NULL INDICATOR is not functioning properly. To check the operation of the NULL INDICATOR, proceed as follows:

1. Select the desired measuring frequency by means of the OSC RANGE and OSC FREQ controls.
2. Set the C_p dial to "O" and the R_p dial to ∞.
3. Unbalance the bridge by shorting the two binding posts and adjusting the DETECTOR TUNING knob until maximum deflection is obtained on the NULL INDICATOR. The meter pointer should indicate about 35 scale divisions. A peak of substantially less than this amount is usually an indication of an unusuable harmonic response instead of the desired fundamental. At higher frequencies, two fundamental frequency peaks will be observed, either of which represents satisfactory tuning of the detector. Several secondary or harmonic peaks, which may be recognized by their relative sharpness and low amplitude, will be observed between the fundamental peaks. Care should be taken not to tune to one of these harmonics, since this will produce erroneous readings or make bridge balance impossible. When maximum meter deflection has been obtained, remove the short from across the binding posts and tighten the binding posts nuts.
4. Balance the bridge by adjusting the three ZERO BALANCE controls, alternately, until a minimum deflection is obtained on the

NULL INDICATOR. The indication should not be more than 3 scale divisions on the meter. At frequencies above 100 Mc, the COARSE R control should be adjusted to its approximate midpoint position before null is sought. Since a slight interaction exists, at high frequencies, between the FINE R and C controls, it is important to use all three controls to obtain final balance. When an apparent null has been obtained, the circuit should be tested for true balance by slowly rocking the R_p dial above and below the setting, and observing the NULL INDICATOR. If a deeper null is observed at some R_p value other than ∞, the R_p dial should be returned to the latter indication and a new balance obtained with the ZERO BALANCE controls.

NOTE: When the measurement frequency is changed, steps 2 through 4 above should be repeated.

5. After the bridge is balanced as described above, set the frequency controls for 0.5 megacycles and change the R_p dial setting from ∞ to 100K. The NULL INDICATOR pointer should deflect upscale and indicate approximately 7 to 12 divisions.

A 10–500 Mc Signal Generator Power Amplifier

ROBERT POIRIER, *Development Engineer*

An increasing demand has developed for higher RF power output levels, in the 0 to 10 dbw maximum output range, over the frequency range from 10 to 500 Mc, for the testing of communications systems and for general laboratory measurements. The need for higher power output signal sources results mainly from strong signal and cross modulation requirements of certain receiver tests and the large input signal requirements of bridge type devices. Because of the large number of existing signal generators in the 0 dbm maximum output category, BRC has developed a tunable signal generator power amplifier for use with these instruments. The signal generator power amplifier is to be an accessory for use with any signal generator having a maximum output in the vicinity of 0 dbm to provide a maximum output level in the vicinity of 4 dbw.

The new Signal Generator Power Amplifier Type 230-A conceived by the Boonton Radio Corporation, consists essentially of three tracked tuned, cascaded stages of grounded-grid amplification. The choice of grounded-grid triode amplification was established primarily by a desire to provide a maximum operating frequency of 500 Mc. Two other advantages which are accrued for grounded-grid triode amplification as compared with grounded cathode tetrodes are: a low untuned input impedance which can be made nominally in the vicinity of 50 ohms, and a gain

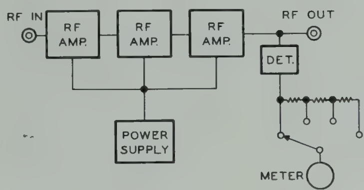


Figure 1. Block Diagram of Signal Generator Power Amplifier Type 230-A

and maximum power output which are less sensitive to variations in load impedance. A minimum of 34 db power gain is to be provided for a frequency coverage of 10-500 Mc which will be continuously tuned in six slightly overlapping ranges. The gain will be linear within 9.0% up to 10 volts output in a 50-ohm termination. This provides that a maximum of 91% AM of a 5-volt carrier level, with 10% distortion of the modulation envelope, will be obtained for a 100% modulated (with no envelope distortion) input signal for which the carrier level approaches 0.1 volt or —7 dbm. The changes in percentage of modulation and envelope distortion which may be developed in the Signal Generator Power Amplifier at the maximum output levels, become negligible for modulation crests of 0.5 watt (5.0 volts rms in 50 ohms) or less. The linearity characteristic of the Signal Generator Power Amplifier is such that, in general, if the outgoing modulation crests exceed 0.5 watt, the modulation index will always be less than the incoming modulation by an amount not exceeding 9.0% of the incoming modulation. Whether, and in which direction, the envelope distortion may be affected at the maximum output levels, depends on the magnitude and phase of the incoming envelope distortion components, if any. The effect should be within ±10% for modulation crests of 10 volts rms in 50 ohms, diminishing to 2% or less for modulation crests of 5 volts rms in 50 ohms or less. The absolute maximum power output over most of the frequency range is 4 watts or 6 dbw (14.14 volts rms in 50 ohms), but the linearity (and gain) is not specified beyond 2 watts or 3 dbw. The overall bandwidth of the three-stage power amplifier is not less than 700 kc and is considerably greater over much of the frequency range.

A block diagram, Figure 1, shows that a self-contained power supply and an output RF voltmeter are included with the Signal Generator Power Amplifier. The RF output voltage is metered from 0-15 volts in four convenient ranges. The detector and the metering circuit will withstand the high voltages which can be developed at the RF output jack when it is unterminated, or terminated in a load having a very high VSWR. The accuracy of the RF output voltage indication is specified at the output jack to be ± 1.0 db of full scale over a frequency range of 10 to 250 Mc and ±1.5 db from 250 Mc to 500 Mc for a 50-ohm termination having a VSWR of 1.0 (0 db) in each case.

An electronically-regulated power supply is incorporated in the Signal Generator Power Amplifier to maintain a constant final amplifier plate voltage against the large variations in final plate current which occur over the range of 0.5 to 4 watts RF output. Other features include 50 ohms input and output impedance with a VSWR of 2.0:1, or less, over the frequency range of 10-500 Mc. RF leakage is sufficiently low to permit measurements at 0.1 volt.

Since the demand for higher power signal generators comes almost exclusively from sources already supplied with low-power signal generators, it is felt that the Signal Generator Power Amplifier will conveniently and readily fulfill this demand, offering up to 2 watts output for AM applications, or or up to 4 watts output for CW and FM, where amplitude linearity is unimportant.

EDITOR'S NOTE
New Look for BRC at IRE

The few weeks preceding the IRE show in March are pandemonium at BRC. Engineering and Sales are steeped in the problems of readying new instruments for showing and assuring that enough advance information is disseminated to stimulate customer interest. Many last-minute details are being attended to and the loose ends are being gathered and knotted .The last days before the show are tumultuous, but those in the midst of the turmoil are aware of the impact of the job they are doing, and in this there is solace.

This year, BRC will show its instrument line in a new display booth; designed not only to provide an attractive setting for instrument display, but to make it easier for BRC engineers in attendance to handle demonstrations and inquiries.

EACH YEAR, IN THE MONTH OF MARCH, A HIGHLY COORDINATED EFFORT IS MADE.....

Of particular interest at the show will be the UHF Q Meter Type 280-A (the subject of the lead article in this issue), the Navigation Aid Test Set Type 235-A (described in Notebook Number 24), and the new Signal Generator Power Amplifier Type 230-A (described in this issue).

Another "guess the Q" contest will be featured for those friends of BRC who welcome the challenge of a perplexing problem. Our engineers have, true to form, devised a resonant circuit which will be on display at the BRC booth. Contestants will be asked to estimate the Q of the circuit, enter this estimate on a contest card, and drop the entry into a special, locked receptacle. After the show, the Q of the resonant circuit will be measured on the UHF Q Meter Type 280-A, by means of the "in circuit" technique. Several measurements will be made and averaged. The entry which is closest to this average measured Q will be awarded a factory-reconditioned Q Meter Type 160-A. In case of a tie, a drawing will be held to determine the winner.

Plan to visit the IRE show at the Coliseum in New York City and stop at the BRC exhibit (Booths 3101 and 3102). Our engineering personnel on duty will be grateful for the opportunity to help you with your test equipment problems.

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BOONTON RADIO CORPORATION

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HELPFUL KIT BUILDING INFORMATION

Before attempting actual kit construction read the construction manual through thoroughly to familiarize yourself with the general procedure. Note the relative location of pictorials and pictorial inserts in respect to the progress of the assembly procedure outlined.

This information is offered primarily for the convenience of novice kit builders and will be of definite assistance to those lacking thorough knowledge of good construction practices. Even the advanced electronics enthusiast may benefit by a brief review of this material before proceeding with kit construction. In the majority of cases, failure to observe basic instruction fundamentals is responsible for inability to obtain desired level of performance.

RECOMMENDED TOOLS

The successful construction of Heathkits does not require the use of specialized equipment and only basic tools are required. A good quality electric soldering iron is essential. The preferred size would be a 100 watt iron with a small tip. The use of long nose pliers and diagonal or side cutting pliers is recommended. A small screw driver will prove adequate and several additional assorted screw drivers will be helpful. Be sure to obtain a good supply of rosin core type radio solder. Never use separate fluxes, paste or acid solder in electronic work.

ASSEMBLY

In the actual mechanical assembly of components to the chassis and panel, it is important that the procedure shown in the manual be carefully followed. Make sure that tube sockets are properly mounted in respect to keyway or pin numbering location. The same applies to transformer mountings so that the correct transformer color coded wires will be available at the proper chassis opening.

Make it a standard practice to use lock washers under all 6-32 and 8-32 nuts. The only exception being in the use of solder lugs—the necessary locking feature is already incorporated in the design of the solder lugs. A control lock washer should always be used between the control and the chassis to prevent undesirable rotation in the panel. To improve instrument appearance and to prevent possible panel marring use a control flat nickel washer under each control nut.

When installing binding posts that require the use of fiber insulating washers, it is good practice to slip the shoulder washer over the binding post mounting stud before installing the mounting stud in the panel hole provided. Next, install a flat fiber washer and a solder lug under the mounting nut. Be sure that the shoulder washer is properly centered in the panel to prevent possible shorting of the binding post.

WIRING

When following wiring procedure make the leads as short and direct as possible. In filament wiring requiring the use of a twisted pair of wires allow sufficient slack in the wiring that will permit the twisted pair to be pushed against the chassis as closely as possible thereby affording relative isolation from adjacent parts and wiring.

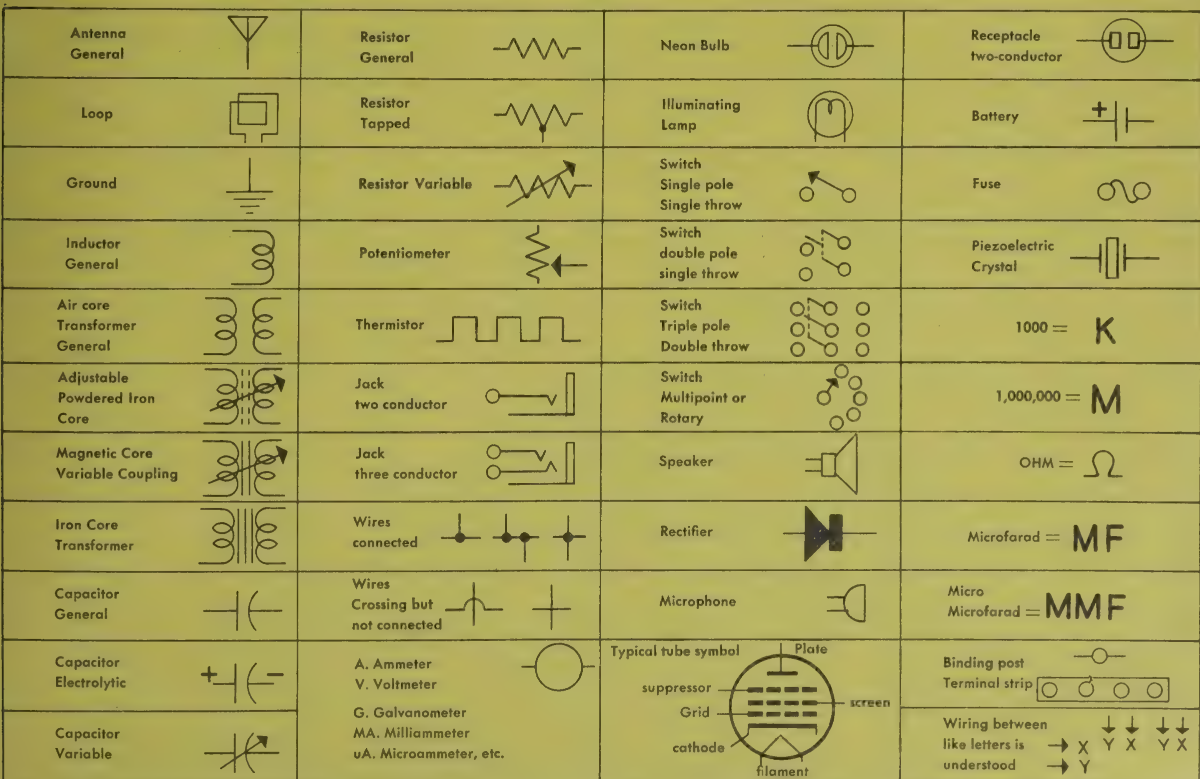
When removing insulation from the end of hookup wire, it is seldom necessary to expose more than a quarter inch of the wire. Excessive insulation removal may cause a short circuit condition in respect to nearby wiring or terminals. In some instances, transformer leads of solid copper will have a brown baked enamel coating. After the transformer leads have been trimmed to a suitable length, it is necessary to scrape the enamel coating in order to expose the bright copper wire before making a terminal or soldered connection.

In mounting parts such as resistors or condensers, trim off all excess lead lengths so that the parts may be installed in a direct point-to-point manner. When necessary use spaghetti or insulated sleeving over exposed wires that might short to nearby wiring.

It is urgently recommended that the wiring dress and parts layout as shown in the construction manual be faithfully followed. In every instance, the desirability of this arrangement was carefully determined through the construction of a series of laboratory models.

SOLDERING

Much of the performance of the kit instrument, particularly in respect to accuracy and stability, depends upon the degree of workmanship used in making soldered connections. Proper soldered connections are not at all difficult to make but it would be advisable to observe a few precautions. First of all before a connection is to be soldered, the connection itself should be clean and mechanically strong. Do not depend on solder alone to hold a connection together. The tip of the soldering iron should be bright, clean and free of excess solder. Use enough heat to thoroughly flow the solder smoothly into the joint. Avoid excessive use of solder and do not allow a flux flooding condition to occur which could conceivably cause a leakage path between adjacent terminals on switch assemblies and tube sockets. This is particularly important in instruments such as the VTVM, oscilloscope and generator kits. Excessive heat will also burn or damage the insulating material used in the manufacture of switch assemblies. Be sure to use only good quality rosin core radio type solder.



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MODEL QM-1

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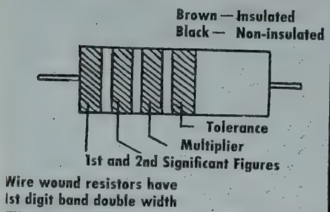
95-52

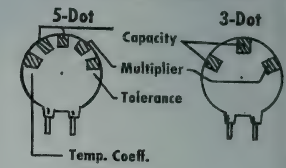
STANDARD COLOR CODE — RESISTORS AND CAPACITORS

AXIAL LEAD RESISTOR

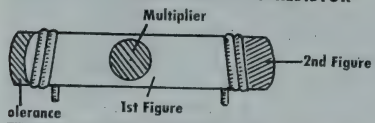


INSULATED UNINSULATED Color	FIRST RING BODY COLOR First Figure	SECOND RING END COLOR Second Figure	THIRD RING DOT COLOR Multiplier
BLACK	0	0	None
BROWN	1	1	0
RED	2	2	00
ORANGE	3	3	,000
YELLOW	4	4	0,000
GREEN	5	5	00,000
BLUE	6	6	000,000
VIOLET	7	7	0,000,000
GRAY	8	8	00,000,000
WHITE	9	9	000,000,000

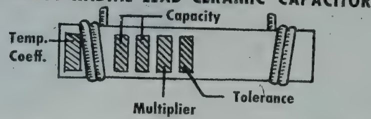
DISC CERAMIC RMA CODE



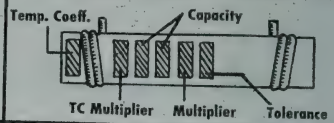
RADIAL LEAD DOT RESISTOR



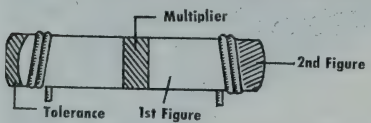
5-DOT RADIAL LEAD CERAMIC CAPACITOR



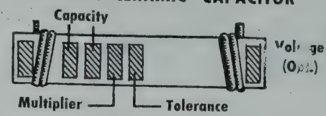
EXTENDED RANGE TC CERAMIC HICAP



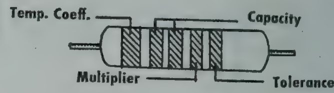
RADIAL LEAD (BAND) RESISTOR



BY-PASS COUPLING CERAMIC CAPACITOR



AXIAL LEAD CERAMIC CAPACITOR

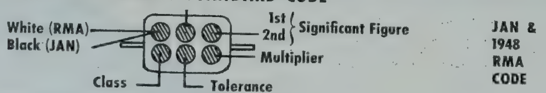


The standard color code provides all necessary information required to properly identify color coded resistors and capacitors. Refer to the color code for numerical values and the zeroes or multipliers assigned to the colors used. A fourth color band on resistors determines tolerance rating as follows: Gold = 5%, silver = 10%. Absence of the fourth band indicates a 20% tolerance rating.

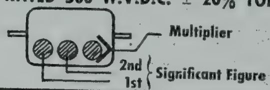
The physical size of carbon resistors is determined by their wattage rating. Carbon resistors most commonly used in Heathkits are ½ watt. Higher wattage rated resistors when specified are progressively larger in physical size. Small wire wound resistors ½ watt, 1 or 2 watt may be color coded but the first band will be double width.

MOLDED MICA TYPE CAPACITORS

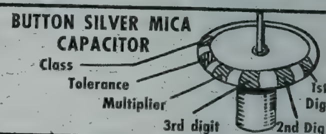
CURRENT STANDARD CODE



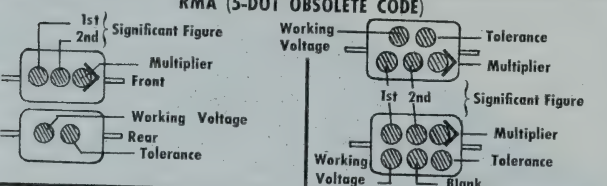
RMA 3-DOT (OBSOLETE) RATED 500 W.V.D.C. ± 20% TOL.



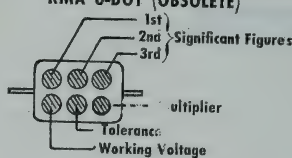
BUTTON SILVER MICA CAPACITOR



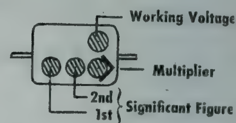
RMA (5-DOT OBSOLETE CODE)



RMA 6-DOT (OBSOLETE)

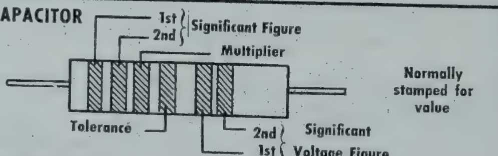


RMA 4-DOT (OBSOLETE)



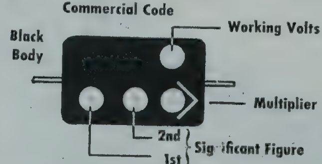
MOLDED PAPER TYPE CAPACITORS

TUBULAR CAPACITOR

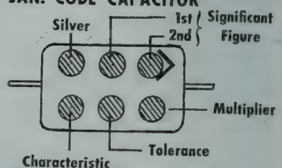


2 digit voltage rating indicates more than 900 V.
Add 2 zeros to end of 2 digit number.

MOLDED FLAT CAPACITOR



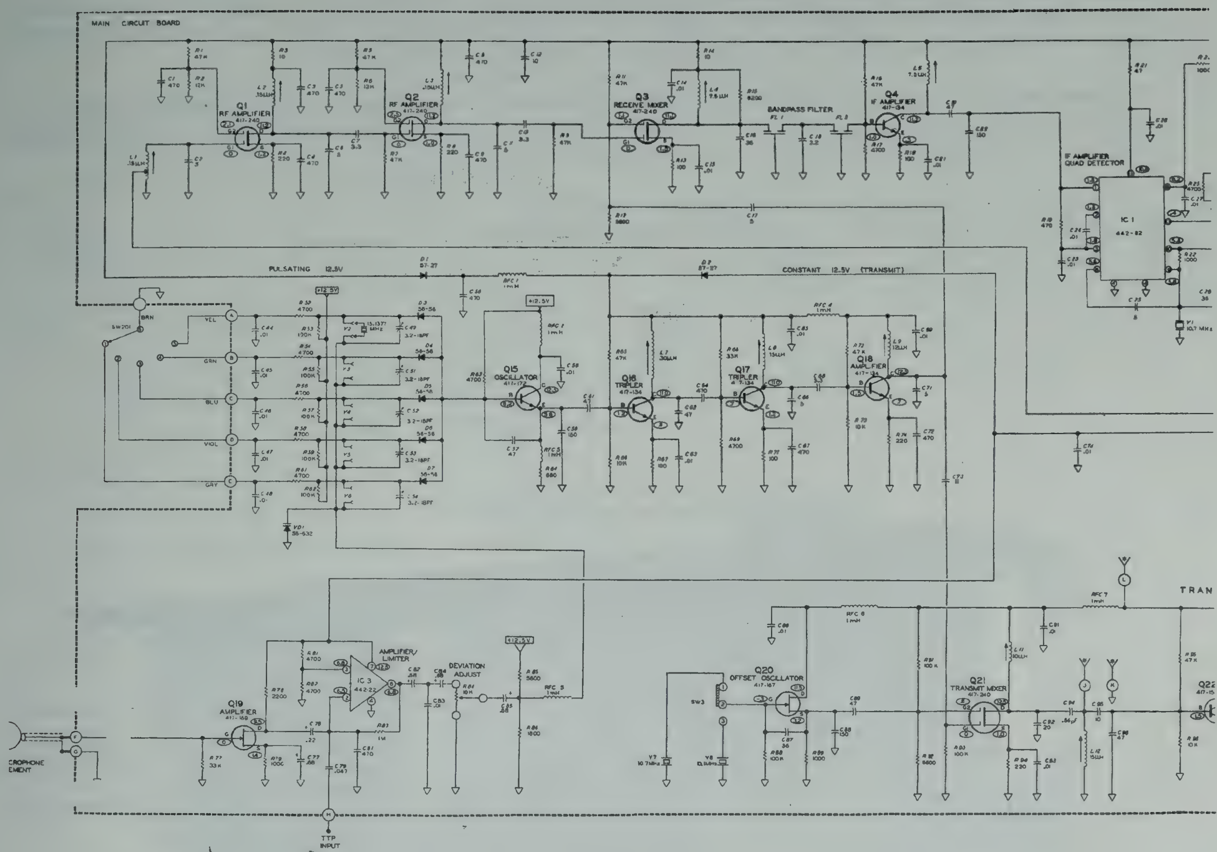
JAN. CODE CAPACITOR



The tolerance rating of capacitors is determined by the color code. For example: red = 2%, green = 5%, etc. The voltage rating of capacitors is obtained by multiplying the color value by 100. For example: orange = 3 × 100 or 300 volts. Blue = 6 × 100 or 600 volts.

In the design of Heathkits, the temperature coefficient of ceramic or mica capacitors is not generally a critical factor and therefore Heathkit manuals avoid reference to temperature coefficient specifications.

Courtesy of Centralab

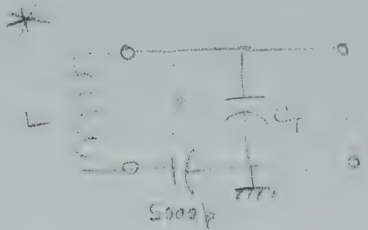

MAIN CIRCUIT BOARD
RF AMPLIFIER
RECEIVE MIXER
BANDPASS FILTER
IF AMPLIFIER
IF AMPLIFIER QUAD DETECTOR
PULSATING 12.5V
CONSTANT 12.5V (TRANSMIT)
OSCILLATOR
TRIPLER
AMPLIFIER
AMPLIFIER/LIMITER
DEVIATION ADJUST
OFFSET OSCILLATOR
TRANSMIT MIXER
TTP INPUT
CROPHONE EMENT
TRAN

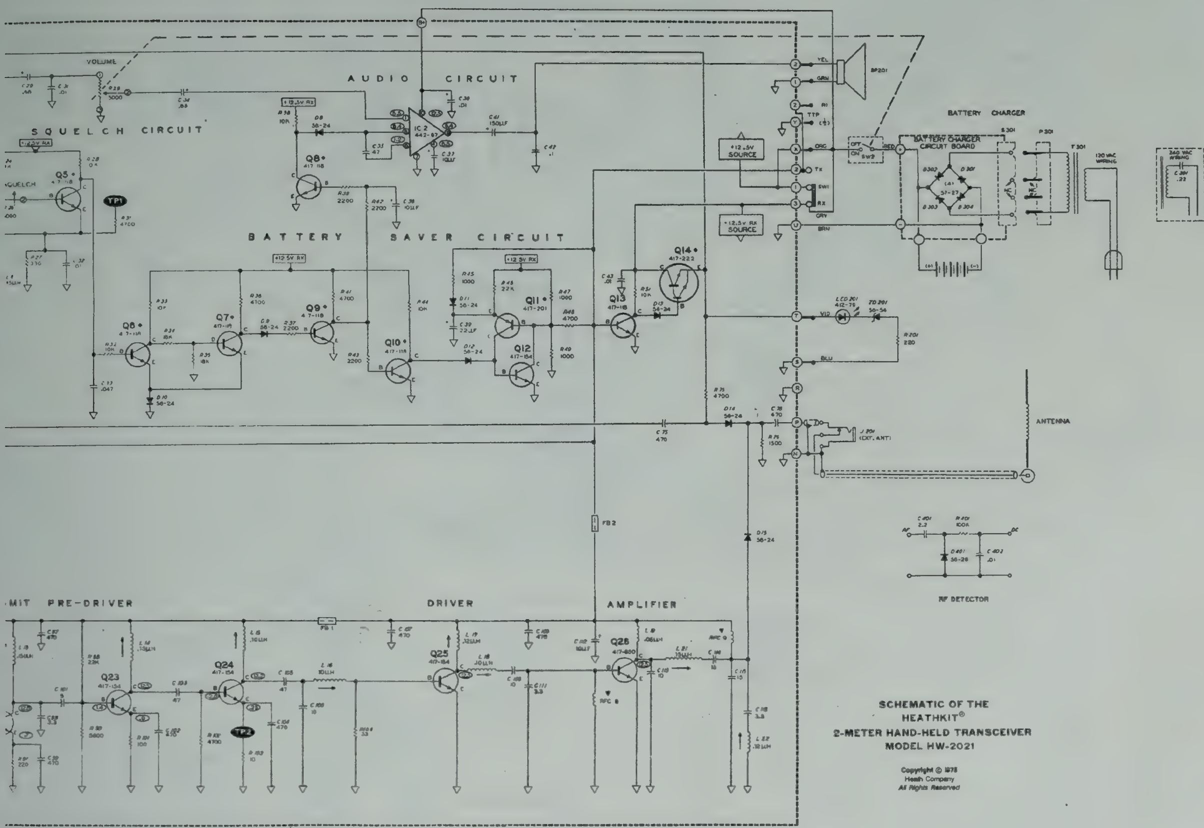
WARRANTY

The Heath Company limits its warranty of any parts supplied with any Heathkit (except tubes, meters and rectifiers, where the original manufacturer's guarantee only applies) to the replacement within three (3) months of said part, which when returned with prior permission, postpaid, was, in the judgment of the Heath Company, defective at the time of sale.

The assembler is urged to follow the instructions exactly as provided. The Heath Company assumes no responsibility or liability for any damages or injuries sustained in the assembly of the device or in the operation of the completed instrument.

HEATH COMPANY
Benton Harbor, Michigan





SCHEMATIC OF THE HEATHKIT® 2-METER HAND-HELD TRANSCEIVER MODEL HW-2021

TABLE 1

SQUELCH CONTROL , FULLY CLOCKWISE, NO INPUT SIGNAL

	E	B	C
Q5	4	1 2	55
Q6	6	1 2	8 0
Q7	6	1 3	8 0
Q8	0	7	1
Q9	0	5	3 6
Q10	0	.7	1
Q11	–	6 0	–

TABLE 2

SQUELCH CONTROL FULLY COUNTER CLOCKWISE, NO INPUT SIGNAL

	E	B	C
Q5	5	0	7.0
Q6	6	6	8
Q7	.6	3	5.0
Q8	0	.3	12.5
Q9	0	7	.1
Q10	0	.1	1.4
Q14	12.5	12.5	11.8

NOTES:

1. COMPONENT NUMBERS ARE IN THE FOLLOWING GROUPS:

   1-199 PARTS ON THE MAIN CIRCUIT BOARD.
   201-299 PARTS IN THE CASE.
   301-399 PARTS IN THE BATTERY CHARGER.
   401-499 PARTS ON THE RF DETECTOR.

2. ALL RESISTORS ARE 1/4-WATT, 5% TOLERANCE, UNLESS OTHERWISE NOTED. RESISTOR VALUES ARE IN OHMS: K=1000, M=1,000,000

3. CAPACITORS EQUAL TO OR LESS THAN .1 ARE IN μF (MICROFARADS). ALL OTHER CAPACITORS ARE IN pF (PICOFARADS) UNLESS OTHERWISE MARKED.

4. INDUCTORS ARE SHOWN IN MH (MILLIHENRIES) AND μH (MICROHENRIES).

5. THIS SYMBOL INDICATES A DC VOLTAGE MEASUREMENT TAKEN WITH A HIGH INPUT IMPEDANCE VOLTMETER FROM THE POINT INDICATED TO CHASSIS GROUND UNDER THE FOLLOWING CONDITIONS:

   A. NO INPUT SIGNAL
   B. SQUELCH CONTROL FULLY CLOCKWISE.
   C. VOLUME CONTROL FULLY COUNTERCLOCKWISE.
   D. LOWEST FREQUENCY OSCILLATOR CRYSTAL SELECTED.
   E. TRANSMITTER VOLTAGES: KEYED WITHOUT MODULATION

6. THIS SYMBOL INDICATES CHASSIS GROUND.

   THIS SYMBOL INDICATES A SOLDERED CONNECTION TO THE MAIN CIRCUIT BOARD.

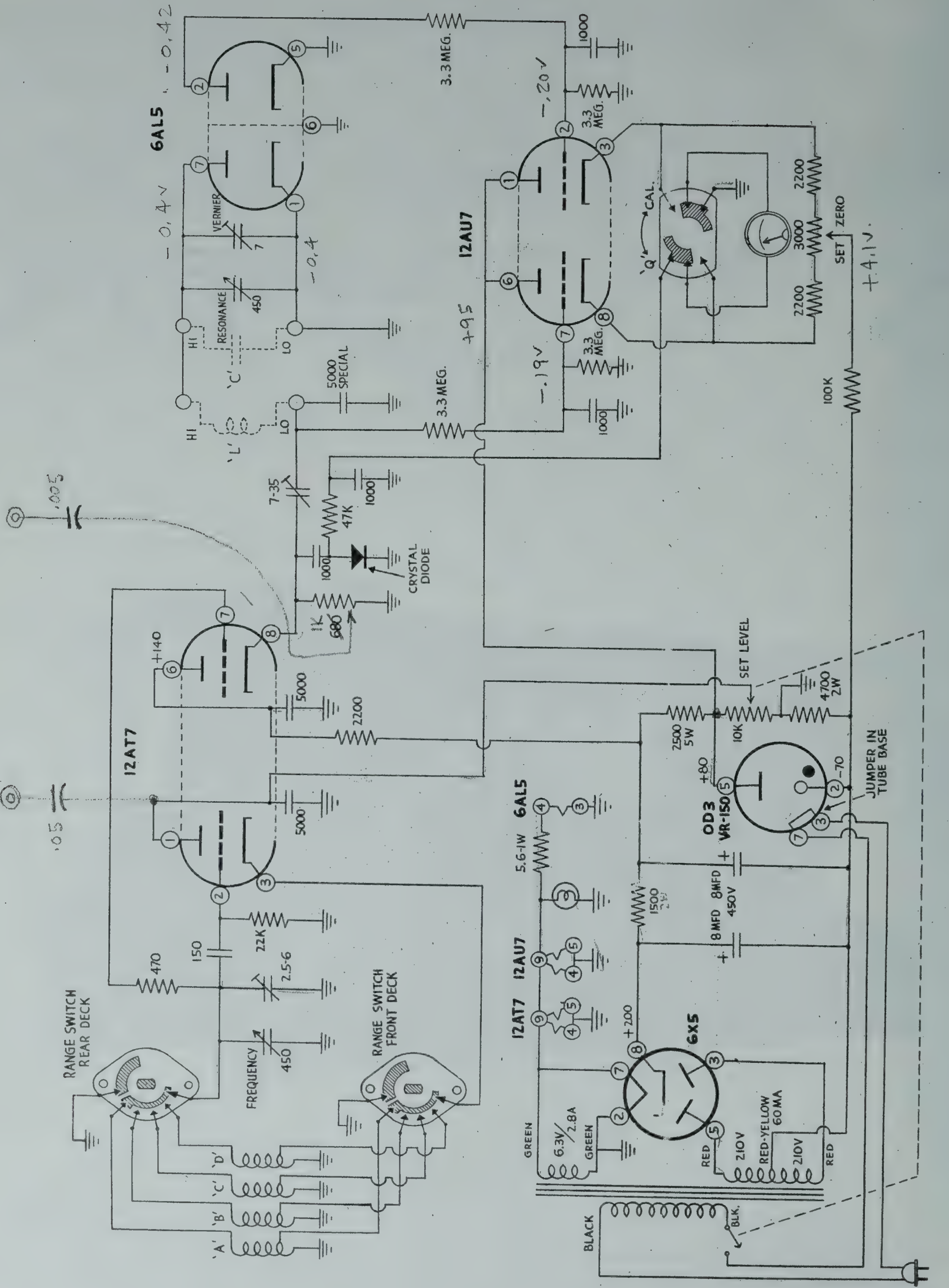
   SEE TABLES 1 AND 2 FOR VOLTAGES.

   THIS SYMBOL DENOTES A CHOKE WOUND BY THE KIT BUILDER.

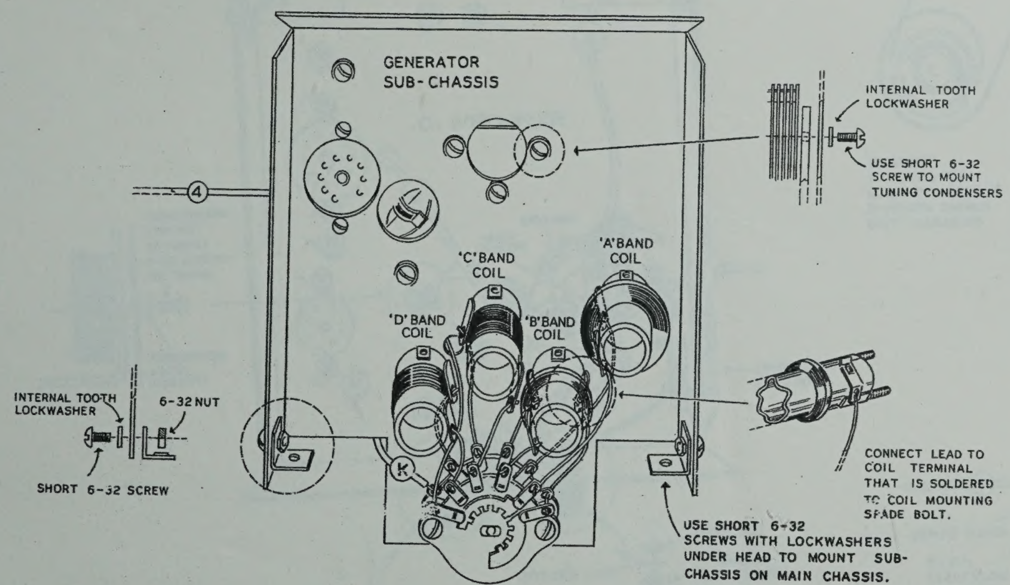
7. REFER TO THE "CIRCUIT BOARD X-RAY VIEWS" FOR THE PHYSIC LOCATION OF PARTS

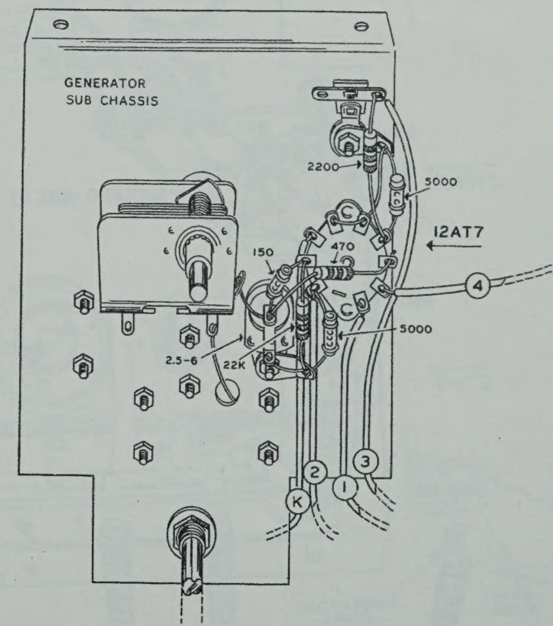
8. TP INDICATES TEST POINT.

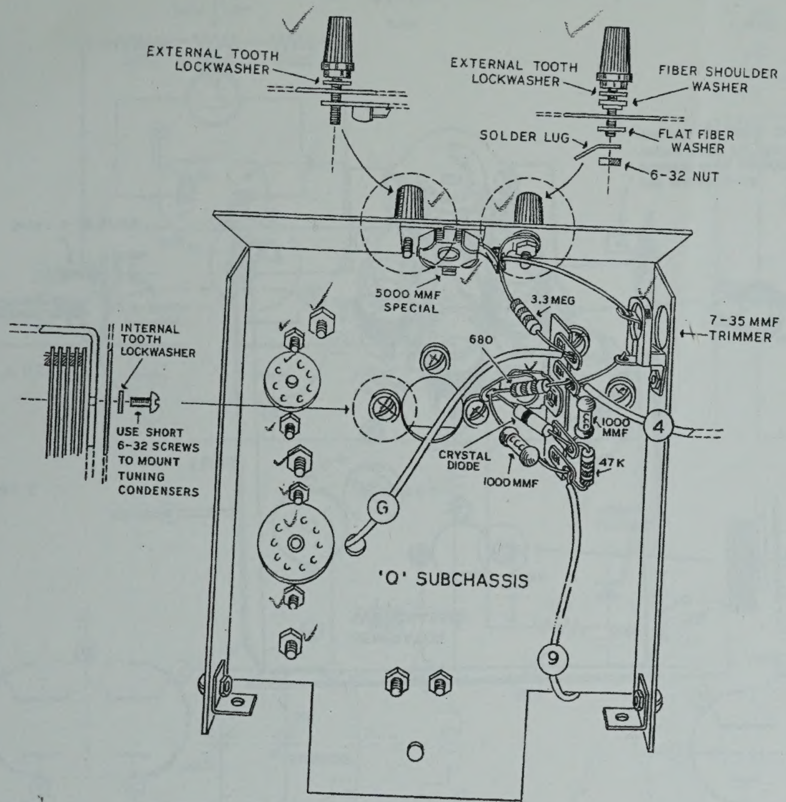
9. * INDICATES TEST POINT USED ONLY WHEN ALIGNMENT I PERFORMED WITHOUT INSTRUMENTS

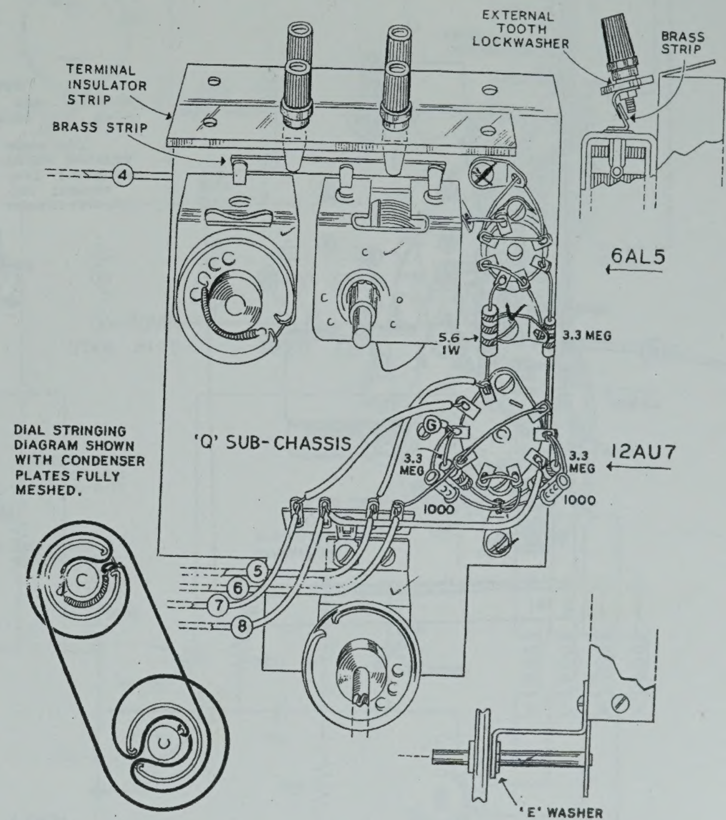


6AL5
3.3 MEG.
1000
3.3 MEG.
12AU7
VERNIER
7
RESONANCE
450
HI
LO
'C'
'L'
5000 SPECIAL
3.3 MEG.
7-35
47K
1000
CRYSTAL DIODE
1K
680
12AT7
+140
5000
2200
SET LEVEL
4700 2W
2500 5W
10K
+80
-70
JUMPER IN TUBE BASE
OD3 VR-150
'Q'
CAL.
2200
3000
SET ZERO
100K
IN
.05
470
150
22K
2.5-6
FREQUENCY
450
RANGE SWITCH REAR DECK
RANGE SWITCH FRONT DECK
'A'
'B'
'C'
'D'
5.6-1W
6AL5
12AT7
12AU7
+200
6X5
8 MFD
8 MFD 450V
1500
GREEN
6.3V/2.8A
GREEN
RED
210V
RED-YELLOW 60MA
210V
RED
BLACK
BLK.
-0.4V
-0.4
-.42
-.20V
+95
-.19V
+4.1V
.005


GENERATOR
SUB-CHASSIS
INTERNAL TOOTH
LOCKWASHER
USE SHORT 6-32
SCREW TO MOUNT
TUNING CONDENSERS
'A'BAND
COIL
'C'BAND
COIL
'D' BAND
COIL
'B'BAND
COIL
4
K
INTERNAL TOOTH
LOCKWASHER
6-32 NUT
SHORT 6-32 SCREW
CONNECT LEAD TO
COIL TERMINAL
THAT IS SOLDERED
TO COIL MOUNTING
SPADE BOLT.
USE SHORT 6-32
SCREWS WITH LOCKWASHERS
UNDER HEAD TO MOUNT SUB-
CHASSIS ON MAIN CHASSIS.


GENERATOR
SUB CHASSIS
2200
5000
12AT7
150
470
4
5000
2.5-6
22K
2
1
3
K


EXTERNAL TOOTH LOCKWASHER
EXTERNAL TOOTH LOCKWASHER
FIBER SHOULDER WASHER
SOLDER LUG
FLAT FIBER WASHER
6-32 NUT
5000 MMF SPECIAL
3.3 MEG
7-35 MMF TRIMMER
INTERNAL TOOTH LOCKWASHER
USE SHORT 6-32 SCREWS TO MOUNT TUNING CONDENSERS
680
1000 MMF
CRYSTAL DIODE
1000 MMF
47 K
4
G
9
'Q' SUBCHASSIS


TERMINAL INSULATOR STRIP
BRASS STRIP
EXTERNAL TOOTH LOCKWASHER
BRASS STRIP
4
6AL5
5.6 1W
3.3 MEG
DIAL STRINGING DIAGRAM SHOWN WITH CONDENSER PLATES FULLY MESHED.
'Q' SUB-CHASSIS
3.3 MEG
3.3 MEG
12AU7
1000
1000
G
5
6
7
8
'E' WASHER